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THE EFFECT OF BORAX ON THE GROWTH AND YIELD OF CROPS.

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INTRODUCTION.

The United States Department of Agriculture issued a report (*12*)[1] early in 1920 on crop injury by borax in fertilizers which was based partly on field experiments conducted in 1919 in cooperation with farmers in the States of Maine, New York, New Jersey, Virginia, North Carolina, South Carolina, and Georgia and partly on investigations of the crop injury by borax in commercial fields of potatoes and cotton in certain Eastern States.

These investigations were made by the department in 1919, as a result of appeals from farmers and fertilizer dealers in many sections of the Eastern States which indicated that important crops to which certain fertilizers had been applied were very seriously affected. As a result of the investigation by the department and by several of the State experiment stations, the trouble was traced to the use of a potash salt containing borax which came from Searles Lake, Calif.

The results of the experiments in the States enumerated above showed that this potash salt containing borax was injurious to potatoes and cotton, but that the degree of injury was dependent upon the type of soil and the climatic conditions. In experiments carried on with potatoes, a decreased yield resulted in some cases where the potash was applied in quantities which would give 7.5 pounds of borax per acre, while in other experiments as much as 18 pounds was required to show injury. In some of the experiments with cotton a reduction in yield resulted where as little as 4 pounds of borax per acre were used, while on other soils no decreased yield resulted with the use of less than 12 pounds.

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[1] Serial numbers (italic) in parentheses refer to "Literature cited" at the end of this bulletin.

That the injury caused by the Searles Lake potash was due to the borax it contained has been further demonstrated by experiments made in 1920. In these tests the effect of Searles Lake potash free from borax gave good results and compared very favorably with potash materials from other sources.

Owing to the great interest taken in the subject and its bearing on crop production it was felt essential to conduct further field studies in order to obtain detailed evidence on the effect of borax upon different crops with respect to growth as well as yield.

This bulletin embodies the results of these field studies conducted cooperatively in the States of Maine, New Jersey, Virginia, and Alabama on several important types of soil.

REVIEW OF THE LITERATURE.

The injurious effects of borax in corn fertilizers were noted in Indiana in 1917 by Conner, which seem to be the first recorded field observations on the effect of borax and its occurrence in fertilizer practice. Conner (*3*) reached the conclusion from his experiments in pots that 100 pounds per acre of a fertilizer containing 2 per cent of borax when applied in the furrow caused injury to the corn plant. Work previous to this by Lipman (*8*) was confined to pot tests, and the work of Cook (*5*, *6*, *7*) was chiefly concerned with the action of borax in manure and is not directly applicable to present-day commercial-fertilizer practice; neither are the experiments of a number of European workers which are reviewed in Cook's paper.

Conner's more recent report (*4*), giving the results of his work with borax on corn in two field experiments, confirms the data obtained from the pot tests. He found that borax caused the greatest injury when the fertilizer in which it was contained was applied in the row. From 0.5 of a pound up to 4 pounds of anhydrous borax per acre produced injury when drilled in the row, and 16 to 18 pounds were required to produce injury when the fertilizer was sown broadcast and worked into the surface soil. Conner also found that borax injury varies with the method of application, type of soil, seasonal conditions, and the crop grown.

In field experiments reported by Blackwell and Collings (*1*), designated a progress report, applications of a potash salt containing 17.75 per cent borax ($Na_2B_4O_7$), used in quantities varying from 25 to 1,000 pounds per acre, did not prevent germination of cotton and corn seed under the conditions of the experiment or hinder the normal growth of the young plants. Their experiments were discontinued when the young plants were 18 inches in height. Nor did applications of commercial borax ranging from 54 to 400 pounds per acre prevent germination and normal growth of either cotton or corn. The planting was followed immediately by heavy rains, which it is stated may account in a large measure for the failure of these quantities of borax to show harmful results. The plantings in these experiments were made late in the summer, and the crops did not mature.

A general survey of the injury to the 1919 potato crop in Maine by borax in fertilizers is given by Morse (*9*), together with a report on pot experiments with borax fertilizer on potatoes, beans, oats, wheat, and buckwheat. Fertilizers applied to soil in pots so as to add 17.6 pounds of anhydrous borax per acre produced severe leaf injury when the fertilizer was mixed in the upper 6 inches of the pot or when placed in the 3 inches of soil below the seed piece. The larger application of borax caused greater root injury and more stunting of the plants, but less tip and marginal injury to the leaves. An application by means of the drill of fertilizer containing anhydrous borax equivalent to 4.4 pounds per acre caused severe injury to beans, while the same fertilizers sown broadcast in quantity equivalent to 8.8 pounds of borax per acre caused no apparent injury to oats, wheat, and buckwheat.

The work of Neller and Morse (*10*) is also very conclusive in showing that borax is extremely poisonous to plants. A number of pot experiments are reported which were conducted under the joint auspices of eight different institutions, namely, the experiment stations of the States of Maine, New Hampshire, Vermont, Massachusetts, Rhode Island, Connecticut, New York, and New Jersey. The work was planned in order to determine whether injury previously observed both in the field and in the greenhouse was due alone to the borax present in the fertilizer applied and to determine the maximum quantity per acre that can be safely applied to land on which important food crops are to be grown. Potatoes, corn, and beans were grown, and borax was applied with fertilizers in quantities varying from 1 to 20 pounds per acre. While these experiments were made in pots and a direct comparison with field conditions can not be made, the results obtained are very valuable and show conclusively that very small quantities of borax can be injurious to plant life. Corn and beans proved to be more susceptible than potatoes to the injurious effects of borax. Three pounds of borax per acre was the largest quantity that could be applied in drills with safety to beans; the limit for corn was under 5 pounds and for potatoes slightly above 5 pounds per acre. Mixing the fertilizer with the soil decreased the injury and slightly raised the quantity of borax that could be applied per acre with safety. These results were obtained with a typical greenhouse potting soil which had a water-holding capacity of 37.5 per cent and was kept at an optimum water content of 19.2 per cent. Subsequent experiments with beans showed that greater injury occurred where the soil moisture was kept at 15.2 per cent than where it was kept at 30.4 per cent.

The damage to crops in North Carolina, principally cotton, tobacco, corn, and peaches, by borax in fertilizers, observed in 1919, is given in a report by Plummer and Wolf (*11*) in which they also include the results of their experimental work. Their experiments, using pots containing a sandy soil to which 5 pounds of borax per acre were applied, showed considerable injury to corn, and when 10 pounds of borax were applied the plants were entirely lacking in green color and soon died. Cotton did not grow where 5 pounds per acre were used. In clay soil both cotton and corn showed marked injury when the quantity of borax exceeded 7 pounds per acre, although in sandy soil as little as 1 pound per acre injured tobacco. The authors state that colloidal absorption is an important factor in enabling plants to tolerate larger quantities of borax when grown on clay soils.

The effect of borax on Sassafras loam (a brown or yellowish brown moderately heavy loam with a reddish yellow subsoil) in New Jersey, as presented by Blair and Brown (*2*), was to depress the yield of potatoes when as much as 30 pounds per acre was used in the drill and the seed planted immediately, while no appreciable decreased yield resulted with 50 pounds when the planting of seed was delayed. With 100 pounds of borax per acre the yield was cut one half. Where fertilizers were sown broadcast 50 pounds of borax per acre markedly decreased the yields. Applications of 100, 200, and 400 pounds of borax per acre either prevented germination or resulted in delayed germination. With corn, where fertilizers were applied in the drill, there was some depression in yield beginning with the 5-pound application, and with 50 pounds per acre and over the injury was severe. When the fertilizer was sown broadcast at the rate of 50 pounds of borax per acre there was a marked decrease in yield. It is noted that the rainfall at New Brunswick during the summer of 1920 was unusually heavy, there being a precipitation of 2.01 inches in the 10 days following the fertilizer application.

In the experiments on the Caribou loam[2] (a yellowish brown silt loam with yellow subsurface soil and gray subsoil) at Presque Isle, Me., injury occurred with an application as low as 5 pounds of borax per acre when put in the furrow and planting done immediately. As the quantity of borax applied increased, the injury became progressively worse. There was a moderate but not excessive rainfall in the early summer, which very likely accounts in part for the difference in the degree of harmfulness shown in this and the New Brunswick experiments.

The results of the investigation with cotton at Muscle Shoals,[3] Ala., on two soil types showed that harmful effects resulted from the use of a quantity of borax as small as 5 pounds per acre. The use of 10 pounds of borax per acre delayed and seriously affected germination. In some cases the plant outgrew its early shock where the smaller quantities were used. The degree of harmfulness of the borax in the experiments planted at different times correlates with the rainfall to a certain extent. When the rainfall was heavy shortly after the fertilizer application was made, the effect of the borax was less.

Other experiments with cotton on both the Clarksville silt loam (a light-gray silt loam with heavy yellowish subsoil) and Colbert silt loam (a gray-brown silt loam with heavy reddish yellow subsoil) were made at Muscle Shoals, Ala., in cooperation with the Fixed-Nitrogen Research Laboratory.

SCOPE AND PLAN OF THE INVESTIGATIONS IN 1920.

Extensive series of tests were made at the department experimental farm at Arlington, Va., on a silty clay loam soil. Corn, Lima beans, snap beans, potatoes, and cotton were grown. Records were kept as to the influence of borax on germination, on early growth, and on the final yield of each crop matured. The records of these experiments, together with the data obtained in some of the experiments located in the States mentioned, are given in detail in this bulletin. Other tests were made cooperatively with the Maine and New Jersey Agricultural Experiment Stations, potatoes being grown on Caribou loam at Presque Isle, Me., and potatoes and corn on Sassafras loam at New Brunswick, N. J.

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[2] Brown, B. E. Effect of borax in fertilizer on the growth and yield of potatoes. U. S. Dept. Agr. Bul. 998, 8 p., 1 fig., 4 pl. 1922.

[3] Skinner, J. J., and Allison, F. E. The influence of fertilizers containing borax on the growth and fruiting of cotton. Unpublished manuscript.

The experiments at Arlington, Presque Isle, New Brunswick, and Muscle Shoals were of the same general plan and afforded an opportunity of studying the effects of borax on five soil types and five crops under different climatic conditions. Borax in all of these experiments was mixed with a fertilizer analyzing 4 per cent NH_3, 8 per cent P_2O_5, and 4 per cent K_2O and the fertilizer applied at a standard rate for each crop, namely, 400 pounds per acre to corn, 1,000 pounds to cotton and to beans, 1,500 to 2,000 pounds to potatoes. Fertilizer free from borax was used as a control. Sufficient borax was added and mixed with the fertilizer so that when applied at the rates just named 1 to 400 pounds of anhydrous borax per acre would be added.

In addition to the experiments made on this general plan at these four locations, other experiments were made at Arlington, Va., with corn and cotton and at Muscle Shoals, Ala., with cotton, using a no-borax fertilizer, one which supplied 5 pounds, another 10 pounds, and a third 20 pounds of borax per acre. These experiments were inaugurated at intervals of about 10 days, to study the influence of weather conditions on the action of borax upon these crops growing on the same type of soil.

The experiments in each location involved applying the fertilizer in three ways: (1) In the seed drill and planting after an interval of a week or 10 days, (2) in the seed drill and planting immediately after applying the fertilizer, (3) broadcasting the fertilizer and planting immediately.

Other experiments with potatoes were made in order to compare the effectiveness of commercial Searles Lake potash, designated 1920 grade, which contained no borax with Searles Lake potash containing borax as it occurred in the trade prior to that year. The latter salt is called the 1919 grade. These experiments were made cooperatively with growers in the potato-producing regions of Virginia, New Jersey, and Maine.

EXPERIMENTS WITH BORAX AT ARLINGTON, VA.

The soil on which the experiments at Arlington were conducted is a silty clay loam, well suited to the growing of vegetables and general farm crops. The land in question was filled with river-bottom material from the Potomac River some ten years ago. It has been tile-drained and in wet seasons does not suffer from an excess of water. In dry seasons it has a sufficient water-holding capacity to support good crop growth. The land was cultivated to corn for several years preceding the inauguration of the borax experiment.

The area used for the experiment was 132 by 400 feet. Each row 132 feet long was divided into three equal sections, providing plats one two-hundred-and-seventieth of an acre in extent. In section 1 the fertilizer was put in the drill, covered and mixed with soil to a depth of about 2 inches and the planting of seed delayed for 7 days.

In section 2 the fertilizer was put in the furrow and otherwise treated as in section 1, except that the seed was planted immediately after the fertilizer was applied. In section 3 the fertilizer was sown broadcast over an area approximately 12 inches wide along the seed furrow.

A fertilizer analyzing 4 per cent NH_3, 8 per cent P_2O_5, and 4 per cent K_2O was applied at the rate of 1,000 pounds per acre to beans, 1,800 pounds per acre to potatoes, and 400 pounds per acre to corn. The materials used in preparing the 4–8–4 mixture were acid phosphate, sodium nitrate, ammonium sulphate, cottonseed meal, and potassium chlorid. Sufficient borax was added and well mixed with the fertilizer so as to apply 1, 2, 3, 4, 5, 10, 20, 30, 50, 100, 200, and 400 pounds of anhydrous borax ($Na_2B_4O_7$) per acre. Five plats were used as checks, and to these was added the fertilizer which contained no borax.

Three adjoining rows were used for each treatment; in the first row Lima beans were planted, in the second snap beans, and in the third potatoes. The experiment with corn was made on plats adjoining those in the truck-crop tests. Records of the effect of the borax on germination, on the growth of the plant in its early stage, and on the yield were made in each case. The daily rainfall was recorded, and this factor will be considered in connection with the experiments.

EFFECT OF BORAX ON LIMA BEANS.

Lima beans were planted in sections 2 and 3 on May 26, immediately after the application of the fertilizers. The seeds in section 1 were planted 7 days later. Each section was planted with 90 seeds and on June 25 thinned to a stand of 70 plants. The experiment was discontinued on September 22, when the vines were cut and weighed green. The beans were picked as they matured, and the yield of beans in the hull as well as vine growth was recorded.

In order to determine the effect of the borax on germination and on early growth, a count of the number of plants in each plat was made one month after date of planting and a measurement made of their height. These data together with the yields are given in Table 1.

The influence of borax on germination can be seen by a study of columns 2, 6, and 10 of Table 1. The data for the two outside control rows are not given, as these were influenced by other experiments in adjoining plats.

In section 1, where the fertilizer was put in the drill and planting delayed for 7 days, the three no-borax or check plats germinated 73, 82, and 83 seeds out of a possible 90. The 400-pound borax plat germinated 4 seeds, the 200-pound plat 37 seeds, and the 100-pound plat 48 seeds. The remaining plats receiving 50 pounds or less germinated fewer seeds than the no-borax plats, but the effect was not so marked as in section 2.

In section 2 only a few seeds germinated in the 100, 200, and 400 pound plats. Less than half germinated in the 30 and 50 pound plats, and a marked effect was produced by the smaller quantities of borax, especially the 10 and 20 pound applications. The three checks in section 2 germinated 82, 75, and 73 seeds, respectively, out of a possible 90.

In section 3, where the fertilizer was sown broadcast, there was a marked effect on germination with 20 pounds of borax per acre; smaller quantities than this had only a slight effect. There was no germination on the 400-pound plat, and only 7 seeds germinated where 200 pounds were used.

TABLE 1.—*Effect of various quantities of borax on Lima beans in field plats on silty clay loam at Arlington, Va., in 1920.*

Borax per acre.	Sec. 1.—Fertilizer applied in drill 7 days before planting.				Sec. 2.—Fertilizer applied in drill at time of planting.				Sec. 3.—Fertilizer applied broadcast at time of planting.			
	Plants up June 25.		Yield per plat (pounds).		Plants up June 25.		Yield per plat (pounds).		Plants up June 25.		Yield per plat (pounds).	
	Number.	Height, inches.	Beans.	Vines.	Number.	Height, inches.	Beans.	Vines.	Number.	Height, inches.	Beans.	Vines.
1	2	3	4	5	6	7	8	9	10	11	12	13
1 pound	72	8.0	25.0	49	60	7.7	21.0	52	80	7.7	23.0	51
2 pounds	75	9.2	26.0	57	52	7.7	22.5	46	63	8.6	26.1	47
3 pounds	62	7.8	26.4	46	60	7.7	23.5	47	58	8.0	25.0	47
None	73	9.4	24.7	43	82	8.7	20.0	47	78	8.9	22.9	49
4 pounds	70	7.5	21.7	42	76	8.1	21.8	44	76	6.8	21.0	46
5 pounds	77	7.0	27.5	45	71	7.4	27.7	46	72	6.8	25.1	43
10 pounds	85	6.8	21.6	48	42	6.7	16.9	37	63	6.3	23.2	41
None	82	9.0	18.8	46	75	9.1	22.8	49	70	8.8	23.5	40
20 pounds	65	6.9	19.7	39	48	6.1	20.8	35	41	5.7	15.9	38
30 pounds	77	6.2	19.8	31	32	5.2	12.0	31	63	5.6	19.2	45
50 pounds	74	5.2	19.0	34	19	3.8	9.5	21	39	4.1	11.7	38
None	83	9.3	19.9	46	73	8.1	16.5	42	83	8.7	17.8	45
100 pounds	48	2.6	5.2	15	9	....	2.6	15	17	....	3.5	15
200 pounds	37	....	4.8	16	8	....	2.4	10	7	....	0	0
400 pounds	4	....	0	0	5	....	0	0	0	....	0	0

Where the fertilizer was applied in the drill, the borax in as small quantities as 1, 2, 3, and 4 pounds per acre had a retarding effect on the early growth of the beans, and 10 pounds of borax markedly stunted the plants. There was not much noticeable depression of growth by borax in quantities under 4 pounds, and when the bean vines reached maturity they had outgrown all injury.

In section 1, 20 pounds of borax decreased the growth of vines, but the production of beans was not influenced by quantities under 100 pounds per acre. In section 2, 10 pounds per acre caused marked depression in the final yield of both vines and beans. In the broadcasted section 20 pounds per acre depressed the production of beans, but vine growth was not influenced by quantities smaller than 50 pounds. There was some stimulation in all sections by the smaller applications.

EFFECT OF BORAX ON SNAP BEANS.

The experiment with snap beans was similar in all details to that of the Lima beans. The seeds were planted on May 26, somewhat thick in the row and thinned to 125 per plat on June 15. They had matured by August 13, on which date the experiment was terminated. The beans were picked weekly, and the record is given in pounds of green beans produced.

The snap beans proved to be very sensitive to borax. During the first month the plants where 1, 2, 3, 4, and 5 pounds of borax were applied in section 2 showed a slightly lighter color of foliage than the no-borax plat, although there was no distinct bleaching. There was a distinct and marked bleaching of leaves with 10 pounds and upward. This effect was distinguished by a curled leaf having yellow and brown tips, and often the entire leaf was affected. This characteristic became severe where 20 pounds were used. These same effects were noticeable in sections 1 and 3, but relatively large quantities were required to produce the symptoms. In section 1 there was no apparent change in color of foliage with quantities under 5 pounds per acre. The complete data are given in Table 2.

TABLE 2.—*Effect of various quantities of borax on snap beans in field plats on silty clay loam at Arlington, Va., in 1920.*

Borax per acre.	Sec. 1.—Fertilizer applied in drill 7 days before planting.				Sec. 2.—Fertilizer applied in drill at time of planting.				Sec. 3.—Fertilizer applied broadcast at time of planting.			
	Plants up June 15.		Yield per plat (pounds).		Plants up June 15.		Yield per plat (pounds).		Plants up June 15.		Yield per plat (pounds).	
	Number.	Height, inches.	Beans	Vines.	Number.	Height, inches.	Beans.	Vines.	Number.	Height, inches.	Beans.	Vines.
None	210	6.2	27.8	37.0	162	7.6	24.7	34.0	132	7.9	25.5	30.0
1 pound	180	6.6	29.6	34.0	154	6.8	26.0	32.0	149	6.5	23.8	29.0
2 pounds	208	4.8	26.7	34.5	93	6.7	22.6	29.0	129	6.7	20.5	29.0
3 pounds	213	5.5	26.7	34.5	91	6.4	20.0	27.0	125	7.0	19.1	26.0
None	203	5.9	24.8	33.0	109	7.0	21.6	31.0	139	7.8	20.8	28.5
4 pounds	180	5.2	21.0	32.0	113	5.5	20.8	27.0	150	6.6	19.2	24.5
5 pounds	224	4.2	19.6	25.5	84	6.0	17.5	21.0	42	5.8	21.2	28.0
10 pounds	208	4.8	19.5	25.5	63	4.6	12.6	16.0	80	4.6	16.7	21.0
None	190	6.4	24.7	33.0	94	6.0	22.4	25.0	128	7.9	20.0	25.0
20 pounds	223	4.1	10.8	15.0	62	3.6	9.2	10.5	103	5.5	12.2	15.5
30 pounds	210	4.1	12.5	17.0	55	4.0	7.3	9.0	83	4.4	8.4	11.5
50 pounds	142	4.0	10.4	15.0	20	3.7	2.4	2.0	68	3.6	7.5	7.5
None	231	5.8	24.3	33.5	115	6.5	21.8	27.0	128	7.5	20.6	24.0
100 pounds	119	3.0	3.6	5.0	27	....	1.1	2.0	28	....	1.1	1.5
200 pounds	58	....	0	0	15	....	0	.7	8	....	0	0
400 pounds	7	....	0	0	13	....	0	0	0	....	0	0
None	203	5.9	23.8	33.5	114	6.5	21.4	25.5	130	7.1	16.8	23.5

Table 2 shows that borax in small quantities materially affected germination, especially in section 2, and that there was considerable retardation in growth in the early life of the plant. The effect on germination and growth is shown in Plate I, Figure 1. The plants shown were dug from the various plats in section 2 on June 15, each being a representative plant from the plat on which it grew. Where 200 and 400 pounds of borax were used, the seeds germinated, but the sprout withered and died without pushing through the soil. The plants from the 50 and 100 pound borax plats were abnormal, weak, and very badly bleached.

The weights of beans and vines tell the story of the final influence of borax on the production of this crop. In sections 1 and 2 its harmful effect is first noticeable with 5 pounds per acre, which increases in degree as the quantity added increases. In the broadcasted section there is not shown much influence from quantities under 10 pounds per acre.

Plates II and III show the Lima and snap beans which were photographed on July 17. In Plate II, Figures 1, 2, and 3 show the Lima and snap beans grown on the no-borax, 5-pound, and 10-pound borax plats, respectively. In Plate III, Figures 1, 2, and 3 show the beans in the 20, 50, and 100 pound borax plats. Figure 3 also shows the plats having 200 and 400 pounds of borax. Here it is seen that these higher borax plats have supported no vegetation whatever. The effect of the varying quantities of borax is apparent and does not call for further comment.

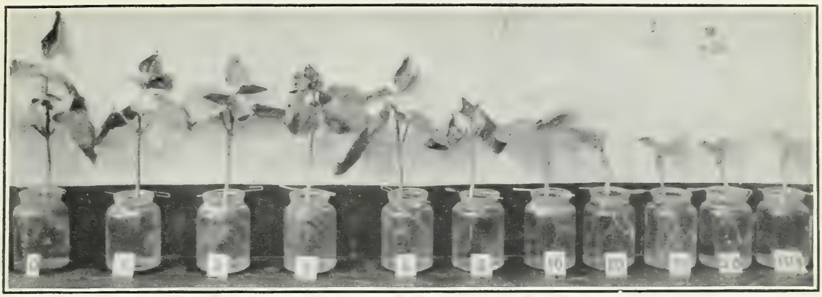
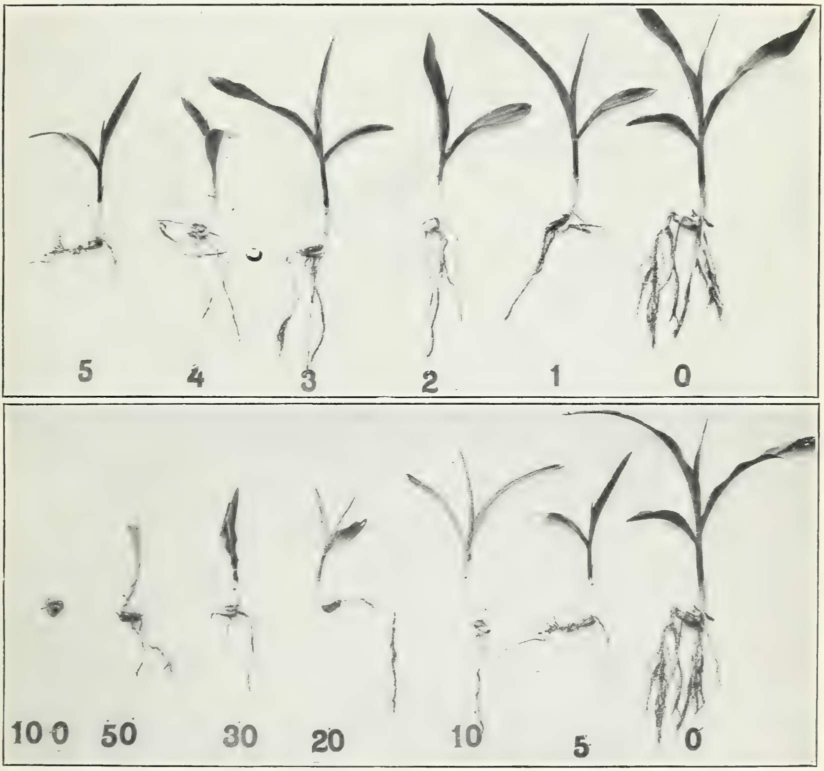


FIG. I.—SNAP BEANS DUG FROM FIELD PLATS TREATED WITH VARIOUS QUANTITIES OF BORAX.

Seeds planted May 26; plants removed from the soil and photographed June 15



FIGS. 2 AND 3.—CORN PLANTS DUG FROM FIELD PLATS TREATED WITH VARIOUS QUANTITIES OF BORAX.

Seeds planted May 3; plants dug from the soil and photographed May 28.

EFFECT OF BORAX ON PLANTS IN THEIR EARLY STAGES OF GROWTH.

The figures shown in connection with the plants indicate the number of pounds of borax applied per acre in the fertilizer used.

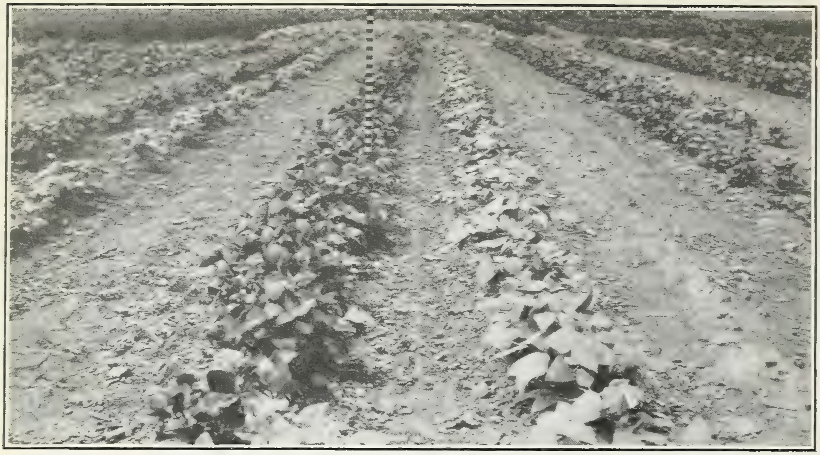


FIG. 1.—NO BORAX APPLIED.

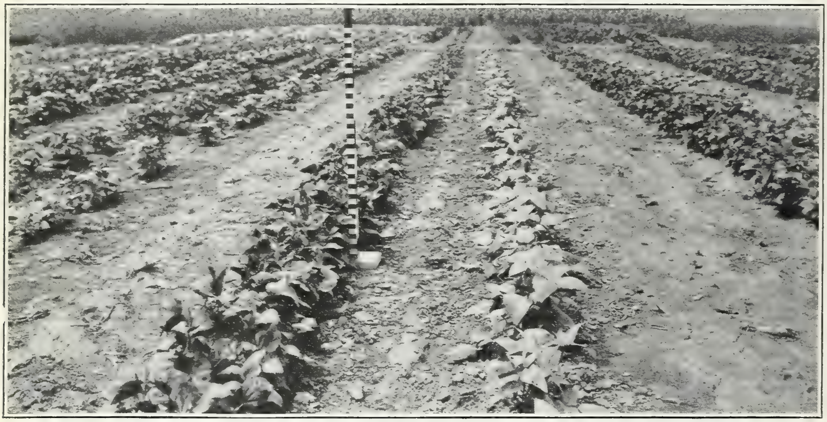


FIG. 2.—APPLICATION OF 5 POUNDS OF BORAX PER ACRE.

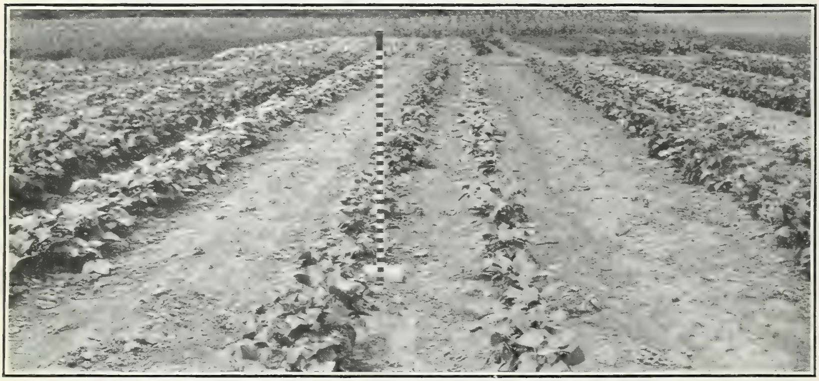


FIG. 3.—APPLICATION OF 10 POUNDS OF BORAX PER ACRE.

EFFECT OF BORAX ON BEANS AT ARLINGTON, VA.—I.

Seeds planted on silty clay loam May 26, using a 4-8-4 fertilizer with and without borax: Snap beans at left, Lima beans at right; plants photographed July 17. (Compare with Pl. III.)

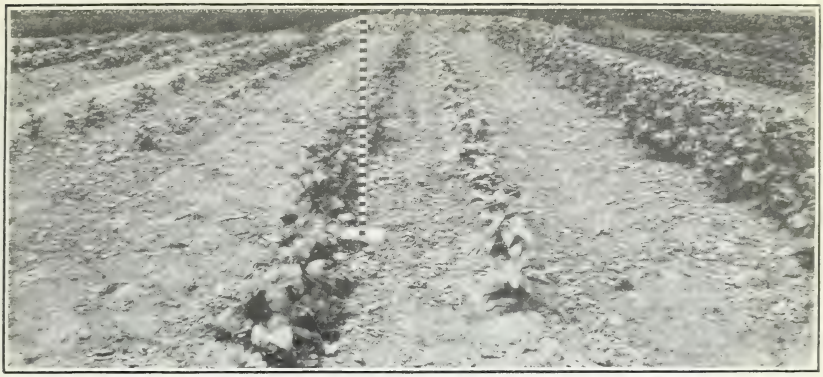


FIG. 1.—APPLICATION OF 20 POUNDS OF BORAX PER ACRE: SNAP BEANS AT LEFT, LIMA BEANS AT RIGHT.

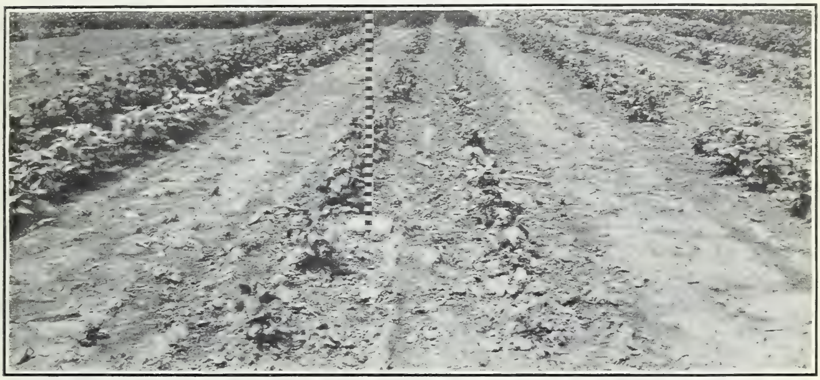


FIG. 2.—APPLICATION OF 50 POUNDS OF BORAX PER ACRE: SNAP BEANS AT LEFT, LIMA BEANS AT RIGHT.

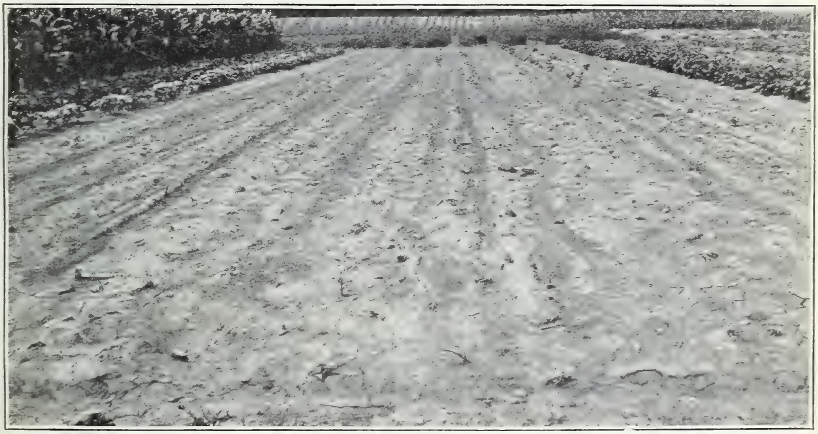
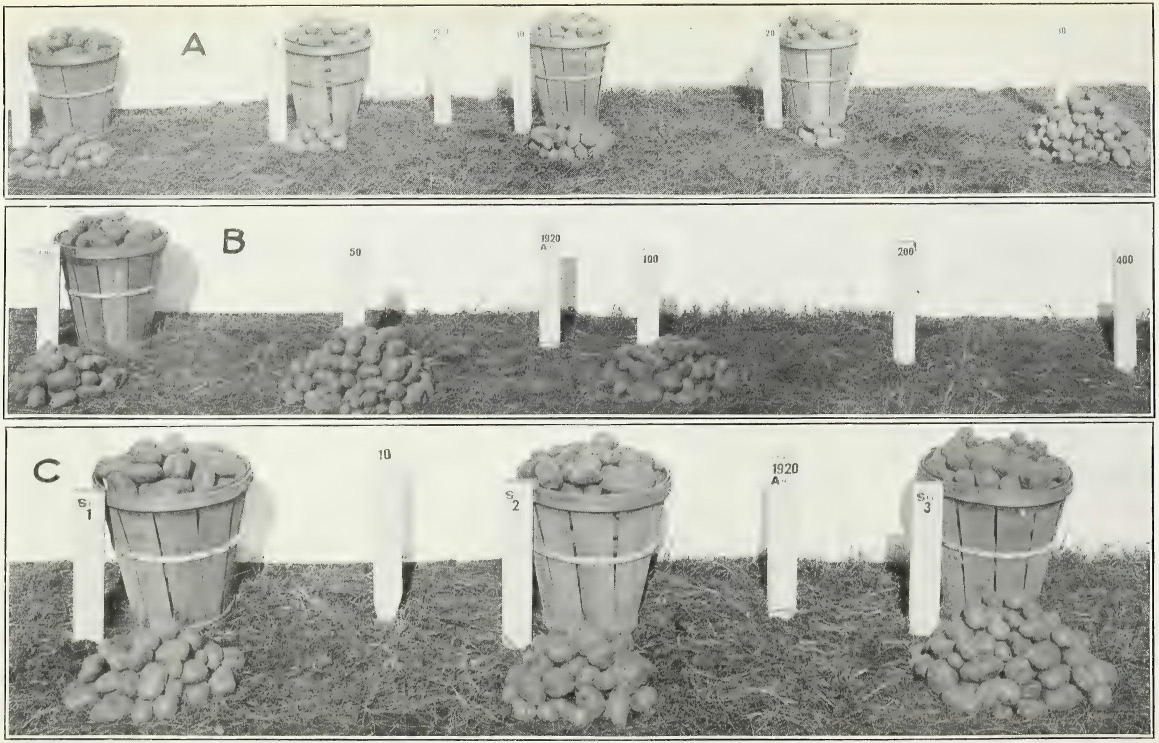


FIG. 3.—APPLICATION OF 100 POUNDS OF BORAX PER ACRE ON RIGHT, 200 POUNDS IN CENTER, AND 400 POUNDS ON LEFT.

EFFECT OF BORAX ON BEANS AT ARLINGTON, VA.—II.

Seeds planted May 26 on silty clay loam, using a 4-8-4 fertilizer with and without borax; plants photographed July 17. (Compare with Pl. II.)



YIELDS OF POTATOES OBTAINED WITH VARIOUS QUANTITIES OF BORAX IN FERTILIZERS AT ARLINGTON, VA

A, No borax, 5, 10, 20, and 30 pounds of borax per acre, respectively. *B*, No borax, 50, 100, 200, and 400 pounds of borax per acre, respectively. *C*, Ten pounds of borax per acre applied by different methods: Sec. 1.—In the drill with delayed planting. Sec. 2.—In the drill at time of planting Sec. 3 —Sown broadcast at time of planting. All plats, 1/270 acre.

EFFECT OF BORAX ON POTATOES.

The potatoes grown in the experiment were McCormicks and were planted on July 1 and dug on October 26. Each of the three sections was planted with 40 seed pieces. The record of the number of pieces that germinated in each plat is given, and it is seen here that the yield is coordinated to a certain extent with the percentage of germination. The rainfall in the first 7 days of July was approximately 2 inches, which was sufficient to thoroughly wet the surface soil a few inches, and the fertilizers doubtless were well diffused in section 1 before the seeds were planted. During July there were 4.97 inches of rainfall and in August 4.91 inches, fairly well distributed, which made conditions ideal for potato growing during the first two months of this experiment.

The yields and the germination records obtained in the experiment are given in Table 3.

TABLE 3.—*Effect of various quantities of borax on potatoes in field plats on silty clay loam at Arlington, Va., in 1920.*

Borax per acre.	Sec. 1.—Fertilizer applied in drill 7 days before planting.			Sec. 2.—Fertilizer applied in drill at time of planting.				Sec. 3.—Fertilizer applied broadcast at time of planting.			
	Yield per plat (pounds).			Yield per plat (pounds).			Plants up July 30.	Yield per plat (pounds).			Plants up July 30.
	Primes.	Culls.	Total.	Primes.	Culls.	Total.		Primes.	Culls.	Total.	
None	34	1	35	39	2	41	40	43	2	45	42
1 pound	38	2	40	45	1	46	43	46	2	48	43
2 pounds	38	1	39	38	2	40	41	50	3	53	44
3 pounds	40	3	43	40	2	42	44	49	4	53	44
None	37	3	40	39	2	41	40	42	3	45	44
4 pounds	40	4	44	54	1	55	44	42	1	43	42
5 pounds	39	1	40	33	1	34	39	45	1	46	44
10 pounds	36	3	39	39	1	40	38	49	1	50	42
None	31	5	36	35	1	36	42	51	1	52	44
20 pounds	32	2	34	30	2	32	35	45	1	46	43
30 pounds	24	2	26	25	1	26	28	45	1	46	44
50 pounds	22	3	25	23	1	24	20	35	1	36	40
None	30	3	33	33	2	35	39	55	1	56	43
100 pounds	14	2	16	14	1	15	9	24	0	24	24
200 pounds	2	2	4	0	0	0	2	0	0	0	4
400 pounds	0	0	0	0	0	0	2	0	0	0	3
None	39	2	41	44	2	46	41	42	2	44	43

In section 1, where the fertilizer was put in the furrow and the planting of potatoes delayed, there was a slight stimulation with the smaller quantities of borax. The yield was depressed by 30 pounds per acre; quantities larger than this proved still more harmful.

In section 2, where the potatoes were planted immediately (Pl. IV, Figs. 1 and 2), the germination was affected, and there was a depression of yield with 20 pounds of borax per acre, while 30 pounds were more harmful. Where 200 and 400 pounds of borax were used there was no germination. In section 3, 50 pounds of borax was the smallest quantity which proved harmful and 100 pounds were decidedly injurious, reducing germination and yield approximately 50 per cent. In Plate IV, Figure 3 shows the effect of 10 pounds of borax per acre in the three sections with different methods of fertilizer application.

The following conclusions can be drawn from the potato experiment: Borax in quantities of 4 pounds per acre and less was stimulating, in harmony with the effect of small quantities of poisons generally; the 5 and 10 pound applications showed no unusual effects; the application of 20 pounds per acre affected germination and reduced the yield when the fertilizer was applied in the drill and the potatoes planted immediately; 30 pounds decreased the growth where the fertilizer was applied in the drill and the planting delayed; and 50 pounds were injurious to germination and depressed the yield where the fertilizer was sown broadcast.

EFFECT OF BORAX ON CORN.

The experiment with corn differed from that with beans and potatoes in that each plat was three rows instead of one, which made the area for each treatment one-ninetieth of an acre instead of one two-hundred-and-seventieth. The fertilizer was applied on May 3, and the seed planted in sections 2 and 3 on that date, while planting in section 1 was delayed until May 12.

The corn was planted thick, using approximately the same number of grains in each plat, afterwards thinning to a stand of 105 plants per section. Before thinning, a record was made of the number of plants which had come up in each plat and the average height of the plants was taken on that date. Notes made 25 days after the seeds were planted (on May 28) showed that in section 2 there was a decided difference in the color of the young plants where 2 and 3 pounds per acre of borax were used. Where 5 pounds were used they were badly discolored and the leaves were slightly curled. In the 10-pound plat the leaves were badly bleached. In section 3, where the fertilizer was sown broadcast, there was no leaf discoloration or bleaching with any quantity under 10 pounds per acre. This characteristic effect was very marked where 20 pounds were used.

A representative plant from each plat in section 2 is shown in Plate I, Figures 2 and 3. Here the characteristic effect of borax is shown. The records showing its effect on germination and on the plant in the early stages of growth, together with the final yields of stover and corn, are given in Table 4.

Borax in quantities as low as 4 pounds per acre slightly depressed the yield of both stover and corn when the fertilizer was applied in the drill. Quantities larger than this decreased the yield considerably more. The use of 20 pounds was very detrimental, and there was an utter failure where 100 pounds were applied.

In the section sown broadcast 20 pounds per acre caused some decrease in yield; the 50-pound application was very harmful; and there was no growth at all where 200 and 400 pounds were used.

Plates V and VI show the corn in section 2 photographed on July 9. The corn in the 3-pound borax plat had not made as much growth as in the no-borax plat, and the corn in the 10-pound plat was a great deal smaller at this stage of its growth than the corn in the no-borax plat. On the 30-pound borax plat shown in Plate VI, Figure 2, the broken stand and uneven growth of the corn is quite striking. An inspection made on July 9 showed that the corn on the no-borax and on the 4-pound borax plats in the broadcasted section of the experiment had made practically the same growth.

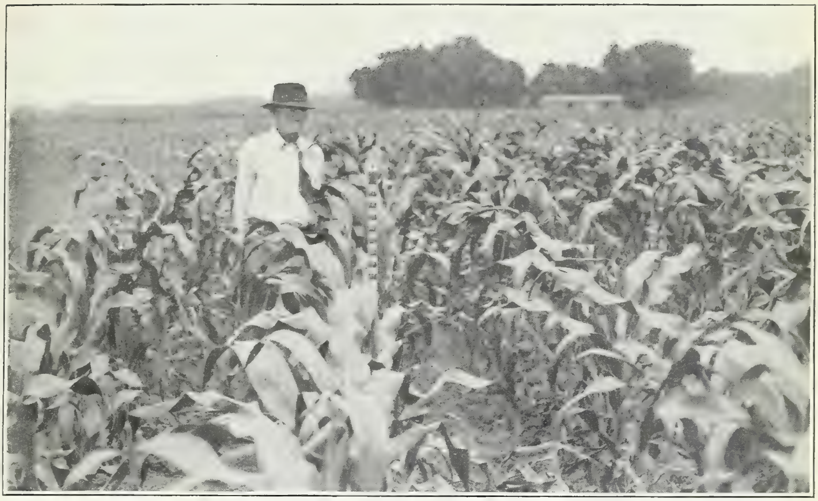


FIG. I.—PLAT TO WHICH NO BORAX WAS APPLIED.

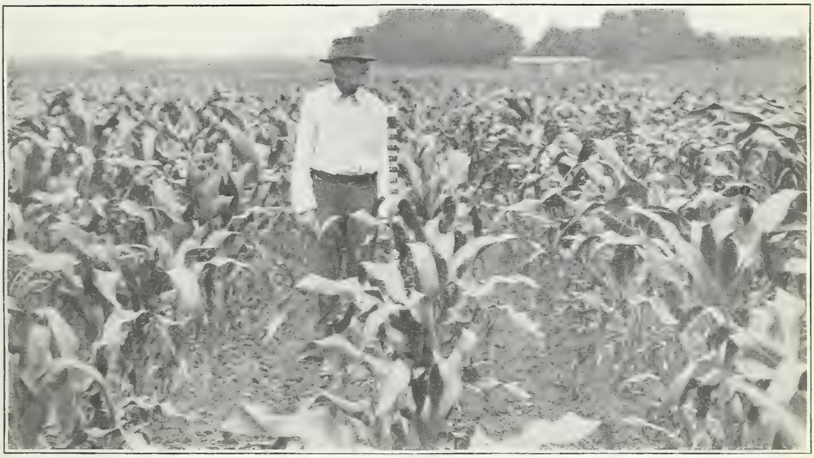


FIG. 2.—PLAT RECEIVING 3 POUNDS OF BORAX PER ACRE.

EFFECT OF BORAX ON CORN AT ARLINGTON, VA.—I.

Fertilizers applied in the drill; seed planted May 7 on silty clay loam; photographed July 9 Compare with Pl. VI.)

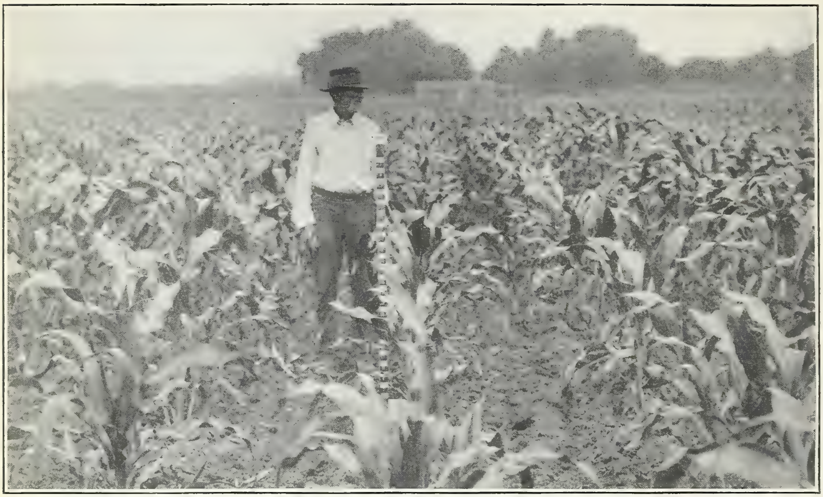


FIG. 1.—PLAT RECEIVING 10 POUNDS OF BORAX PER ACRE.

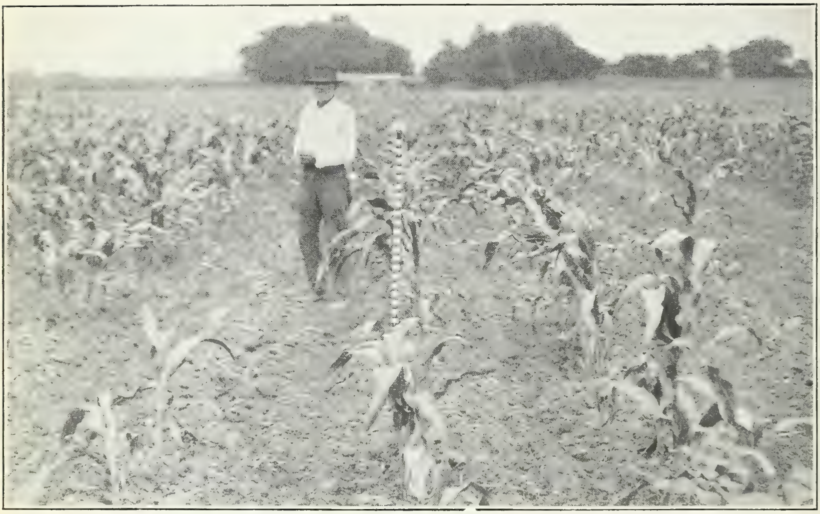


FIG. 2.—PLAT RECEIVING 30 POUNDS OF BORAX PER ACRE.

EFFECT OF BORAX ON CORN AT ARLINGTON, VA.—II.

Seed planted May 7 on silty clay loam; fertilizers applied in the drill; photographed July 9
(Compare with Pl. V.)

TABLE 4.—*Effect of various quantities of borax on corn in field plats on silty clay loam at Arlington, Va., in 1920.*

Borax per acre.	Sec. 1.—Fertilizer applied in drill 7 days before planting.				Sec. 2.—Fertilizer applied in drill at time of planting.				Sec. 3.—Fertilizer applied broadcast at time of planting.			
	Plants up June 8.		Yield per plat, pounds.		Plants up May 28.		Yield per plat, pounds.		Plants up May 28.		Yield per plat, pounds.	
	Number.	Height, inches.	Stover.	Ears.	Number.	Height, inches.	Stover.	Ears.	Number.	Height, inches.	Stover	Ears.
None	207	8.6	153	106	214	6.5	136	91	237	6.0	120	96
1 pound	177	8.1	147	81	221	5.2	118	88	244	5.5	113	91
2 pounds	167	7.7	136	96	191	4.5	113	89	206	4.8	123	81
3 pounds	194	8.0	147	93	209	3.7	135	80	208	4.2	92	84
None	170	8.6	156	94	210	5.5	132	87	202	5.6	122	90
4 pounds	162	7.9	120	87	179	4.2	128	72	156	4.5	131	84
5 pounds	145	7.0	131	86	168	4.1	125	75	184	4.6	131	97
10 pounds	153	5.9	114	89	111	3.2	116	72	180	4.3	131	92
None	170	8.5	146	94	225	5.5	140	97	229	5.4	148	96
20 pounds	127	5.7	129	87	76	3.1	107	71	175	4.0	142	85
30 pounds	74	5.3	90	66	70	3.4	90	60	187	3.9	140	54
50 pounds	51	4.9	75	44	24	....	82	59	44	....	72	56
None	177	8.7	157	105	211	5.5	156	109	182	5.6	133	100
100 pounds	26	3.5	50	33	9	....	17	9	77	....	74	64
200 pounds	6	3.4	16	13	7	....	18	10	0	....	0	0
400 pounds	0	0	0	0	9	....	0	0	1	....	0	0
None	189	8.4	135	96	133	5.2	137	99	82	4.3	115	86

In section 1, as far as concerns the 200 and 400 pound plats, nothing grew. Where borax was sown broadcast over the entire area and mixed with the soil the growth of either grass or weeds was prevented throughout the entire summer. In section 2 these same plats allowed only a few plants to mature, and these were outside the drill rows.

From the data presented in the foregoing pages it is apparent that borax is injurious to plant growth. The degree of harmfulness seems to vary considerably with the crop grown and the method of applying the fertilizer. It is apparent from the data presented in this bulletin and from the work of others previously cited that borax is much less harmful when sown broadcast than when concentrated in the drill. Weather conditions following the time of applying the fertilizer and during the early life of the crop are an important factor which influences the action of the borax, as was pointed out in considering the work already reported.

INFLUENCE OF RAINFALL ON THE EFFECT OF BORAX.

A daily record of the rainfall at Arlington was kept, which affords an opportunity to study its influence on the effect of borax on the various crops. The daily rainfall for May, June, July, August, and September is given in Table 5.

Considering first the weather conditions connected with the planting of beans on May 26, it is seen from a study of the rainfall record that there was no precipitation for 10 days preceding the application of the fertilizer and none for 10 days following the inauguration of the experiment. The first rainfall occurred on June 5, amounting to 1.19 inches. The rainfall for the remainder of the month was well distributed and was sufficient to keep the soil in good moist condition. At the time of planting the beans and for 10 days following the soil was dry. This period was followed by two weeks of optimum soil-moisture conditions. The effect of the borax in retarding the germination of the beans and stunting the growth of the young plants was probably more pronounced than if there had been heavy rainfall for this period.

TABLE 5.—*Record of daily rainfall at Arlington, Va., for the five-month period from May to September, inclusive, in 1920.*

[Data in inches.]

Date.	May.	June.	July.	Aug.	Sept.	Date.	May.	June.	July.	Aug.	Sept.
1	0.38	0	0	0	0	17	0	0.21	0.07	0.18	0
2	0	0	0	.44	0	18	0	.21	.08	.16	0
3	0	0	1.96	0	0	19	0	0	0	.17	0
4	0	0	0	0	0	20	0	0	.89	.80	0
5	0	1.19	0	0	0	21	0	1.25	0	1.00	0
6	0	.83	0	.26	0	22	0	.15	0	0	0
7	0	0	0	.01	.22	23	0	0	.22	.11	0
8	.41	0	.62	0	0	24	0	.04	0	0	0
9	0	0	0	0	0	25	0	.24	.80	0	.03
10	0	0	0	.04	1.09	26	0	0	0	0	0
11	0	0	0	.38	.70	27	0	0	0	0	0
12	0	.25	0	0	0	28	0	0	0	.18	.07
13	.76	0	0	.71	.01	29	0	0	0	0	.02
14	0	.05	0	0	0	30	0	0	0	.11	1.34
15	.05	0	.31	0	0	31	0	....	0	0	....
16	0	.09	.02	.36	0						

The weather conditions at the time of planting the potatoes on July 1 were somewhat different. For 10 days preceding the inauguration of the experiment about 1 inch of rain had fallen, and the soil was sufficiently moist to cause germination and to support normal growth. On July 3, two days after the fertilizer was applied and the seed planted in sections 2 and 3, there was a rainfall of 1.96 inches. While this depth of rainfall would not be likely to cause any considerable quantity of borax to be leached, it probably would be sufficient to dissolve the borax. By the natural movement of the soil moisture the borax would be well diffused in the soil. The borax in section 1, where the delayed planting was made, was probably well distributed before planting was done. Occasional rains during July kept the soil well supplied with moisture except in the last of the month, when a period of about a week without rainfall occurred. The rainfall in August was favorable, so that the potatoes germinated and grew under rather favorable moisture conditions, and only slight borax injury was experienced. It required relatively large quantities to produce a pronounced injury.

The corn which was planted early in May started its growth under somewhat different weather conditions than did the beans and potatoes. When planted on May 3 the soil was in a good moist condition and during the following 12 days there was a well-distributed rainfall of 1.22 inches, which was during the germination stage. The rainfall was sufficient to keep the surface soil in a moist condition, and at no time during the 12-day germinating period did the surface become dry. The following 3 weeks, which was the period when the young plants were beginning their growth, were without rainfall, As was pointed out earlier, there was considerable injury to the young corn by small quantities of borax, except possibly in the 3 plats of section 1 which received 1, 2, and 3 pounds of borax per acre.

It would seem that weather conditions at the time of planting exerted considerable influence on the effect of borax on the crops in the Arlington work. As this was apparent early in the investigation, experiments with corn and cotton were planned and inaugurated early in June to determine especially the effect of rainfall and weather conditions on the action of borax. Experiments with these two crops were begun on June 2 and repeated at intervals of about one week for a number of weeks.

PERIODIC PLANTING OF CORN AND COTTON.

CORN.

The experiments planned especially to study the effect of borax under different weather conditions were similar in design to the former experiments described as far as the method of applying the fertilizer is concerned. Only two quantities of borax were used, however, namely 5 and 10 pounds per acre, and these are compared with a fertilizer containing no borax. Each treatment comprised one row 44 feet long, which is one two-hundred-and-seventieth of an acre. The outline of the experiments with dates on which each was inaugurated is given in Table 6, together with the data obtained.

TABLE 6.—*Influence of weather conditions on the action of borax on corn at Arlington, Va., in 1920.*

Experiment, date started, and borax per acre.	Yield per plat.											
	Sec. 1.—Fertilizer applied in drill 7 days before planting.				Sec. 2.—Fertilizer applied in drill at time of planting.				Sec. 3.—Fertilizer applied broadcast at time of planting.			
	Stover.	Increase or decrease.	Ears.	Increase or decrease.	Stover.	Increase or decrease.	Ears.	Increase or decrease.	Stover.	Increase. or decrease	Ears.	Increase or decrease.
Series A, June 2:	*Lbs.*	*P. ct.*	*Lbs.*	*P. ct.*	*Lbs.*	*P. ct.*	*Lbs.*	*P. ct.*	*Lbs.*	*P. ct.*	*Lbs.*	*P. ct.*
None	30	....	25	....	32	....	24	....	33	....	31	....
5 pounds	45	+50	31	+24	44	+37.5	33	+37.5	41	+24.2	36	+16.1
10 pounds	33	+10	28	+12	39	+21.9	34	+41.7	34	+ 3	32	+ 3.2
Series B, June 9:												
None	33	....	24	....	67	....	39	....	53	....	38	......
5 pounds	29	−12.1	20	−16.7	47	−29.8	28	−28.2	46	−13.2	33	−13.1
10 pounds	28	−15.1	19	−20.8	50	−25.4	33	−15.4	58	+ 9.4	46	+21
Series C, July 7:												
None	132	....	......	....	138	....	......	....	153	....	......	......
5 pounds	133	+ .75	......	....	137	− .7	......	....	143	− 6.5	......	......
10 pounds	123	− 6.8	......	....	97	−30	......	....	126	−17.6	......	......
Series D, July 15:												
None	93	....	......	....	122	....	......	....	124	....	......	......
5 pounds	89	− 4.3	......	....	109	−10.6	......	....	117	− 5.6	......	......
10 pounds	64	−31.2	......	....	97	−20.5	......	....	127	+ 2.4	......	......
Series E, August 3:												
None	81	....	......	....	91	....	......	....	91	....	......	......
5 pounds	82	+ 1.23	......	....	73	−19.8	......	....	76	−16.5	......	......
10 pounds	66	−18.5	......	....	58	−36.2	......	....	71	−22	......	......

In the first experiments of the series, A, the fertilizers were applied on June 2, and the seeds were planted on that date in sections 2 and 3 and on June 9 in section 1. There was an increased yield of both stover and corn in the 5 and 10 pound borax plats in each section over the no-borax plat. There was a marked stimulation apparently due to borax, which was as much as 50 per cent in stover in one case and 37.5 per cent in ear production in another case. The third day after the fertilizers were applied there was a rainfall of 1.19 inches and the fourth day 0.83 inch. This depth of moisture falling in 2 days undoubtedly diffused the borax in the soil. At any rate the borax in the quantities applied, 5 and 10 pounds per acre, under these weather conditions had no harmful action.

In series B, which was started on June 9, the borax caused some decrease in both stover and corn. This decrease was most severe in section 2, where the yield of stover was decreased nearly 30 per cent and of ears 28.2 per cent by 5 pounds of borax. The yield of stover was decreased 25.4 per cent and that of ears 15.4 per cent by 10 pounds of borax. At the time of applying fertilizers and planting the soil was moist, but there had been no rain for several days. The light showers which fell within the 10 days following the planting were not more than would moisten the surface inch of soil.

Series C was not planted until July 7, and no yield of ear corn was produced by this and the subsequent planting, as the planting was made too late in the season to mature. The yield of stover, however, is given. The effect of the borax in this planting was to cause no decrease with 5 pounds in section 1, and only slight decreases in sections 2 and 3. The decrease with 10 pounds was more marked in sections 1 and 3 and especially in section 2, where it was as much as 30 per cent. The soil was moist at planting time, and there was 0.62 of an inch precipitation the next day, after which there was no precipitation for a week. The second week after planting there were light showers daily which were sufficient to keep the surface moist.

Series D was planted on July 15, and the action of the borax was somewhat more severe than in series C. A slightly decreased yield in each section was caused by 5 pounds of borax. The use of 10 pounds of borax caused a considerable decrease in sections 1 and 2, but a slight increase in section 3. The first 10 days after this experiment was begun the soil was rather moist. There were light showers for the 4 days following the planting, amounting in all to 0.48 of an inch rainfall, and on the sixth day, July 20, there was 0.89 inch precipitation.

The last planting was made on August 3, and series E in Table 6 shows that the borax was harmful to growth in sections 2 and 3 with 5 pounds per acre, and its harmful effects were very marked in each section where 10 pounds were used, amounting to a decrease of 36.2 per cent in growth in section 2. The rainfall in the 10-day period following the planting was moderate, amounting to 0.69 of an inch, which was well distributed. In the second 10-day period, 3.38 inches precipitation occurred, but this, too, was well distributed, and there were no heavy rains during the 20-day period.

In each of these series, excepting A, the borax had a harmful action. However, the degree of harmfulness in the several series varied, and in series C it was very mild. The experiments generally were made under favorable moisture conditions, the depth of rainfall which occurred shortly after the fertilizer was applied in each test did not vary greatly, except in series A, where there was a precipitation of 2.02 inches in the four days following the fertilizer application, and in series C, where the planting was followed on the second day by a rainfall of 0.62 of an inch.

COTTON.

Experiments with the Cleveland Big Boll variety of cotton similar to those with corn just described were also made and some interesting results obtained. Cotton planted as late as June at Arlington could not mature. The effects of borax, however, were noted on germination, growth, and boll formation. In these tests each treatment occupied one row or an area of one two-hundred-and-seventieth of an acre. The 4–8–4 fertilizer was used at the rate of 1,000 pounds per acre. The cotton was planted thick and thinned to 45 hills per plat, with 2 plants to each hill. The complete data are given in Table 7.

TABLE 7.—*Effect of various quantities of borax on the growth and fruiting of cotton on silty clay loam at Arlington, Va., in 1920.*

[The measurements of height of plants were made in experiment series A and B, for sections 2 and 3, on July 27; for section 1, on August 3; those for experiment series C, sections 2 and 3, on August 3, and for section 1, on August 10.]

Experiment, date started, and borax per acre.	Yield per plat.														
	Sec. 1.—Fertilizer applied in drill 7 days before planting.					Sec. 2.—Fertilizer applied in drill at time of planting.					Sec. 3.—Fertilizer applied broadcast at time of planting.				
	Plants.		Increase or decrease.	Bolls and squares.	Increase or decrease.	Plants.		Increase or decrease.	Bolls and squares.	Increase or decrease.	Plants.		Increase or decrease.	Bolls and squares.	Increase or decrease.
	Height.	Weight, green.				Height.	Weight, green.				Height.	Weight, green.			
Series A, June 2:	*Ins.*	*Lbs.*	*P. ct.*	*No.*	*P. ct.*	*Ins.*	*Lbs.*	*P. ct.*	*No.*	*P. ct.*	*Ins.*	*Lbs.*	*P. ct.*	*No.*	*P. ct.*
None	16.9	61	......	1,680	......	12.5	60	......	1,777	......	14.8	73	......	1,435	......
5 pounds	12.4	56	− 8.2	1,295	−22.9	11.6	59	− 1.7	1,000	−43.7	14.1	80	+ 9.6	1,252	−12.7
10 pounds	11.2	58	− 5	1,315	−21.7	10.1	61	+ 1.7	967	−45.6	11.0	55	−24.7	901	−37.2
Series B, June 9:															
None	8.8	67	......	1,478	......	11.5	72	......	1,441	......	13.0	72	......	1,525	......
5 pounds	8.1	69	+ 3	1,400	− 5.3	7.3	62	−14	1,305	− 9.4	10.0	79	+ 9.7	1,503	− 1.4
10 pounds	6.9	67	0	1,302	−11.9	6.5	58	−19.5	1,361	− 5.6	8.8	68	− 5.6	1,600	+ 5
Series C, June 18:															
None	9.6	62	......	1,500	......	10.2	69	......	1,697	......	10.7	68	......	1,692	......
5 pounds	7.0	62	0	1,590	+ 6	9.6	70	+ 1.4	1,750	+ 3.1	9.1	71	+ 4.4	1,800	+ 6.4
10 pounds	6.7	57	− 8	1,490	− .7	8.7	72	+ 4.4	1,505	−11.3	7.8	64	− 5.9	1,613	− 4.7
20 pounds	6.5	56	− 9.7	1,380	− 8	6.8	49	−29	1,480	−12.8	7.2	53	−22	1,520	−10.2
Series D, July 7:															
None	.....	40	......	1,100	......	.....	45	......	1,539	......	.....	54	......	1,610	......
5 pounds	.....	37	− 7.5	1,000	− 9.1	.....	49	+ 8.9	1,392	− 9.5	.....	51	− 5.6	1,630	+ 1.2
10 pounds	.....	29	−27.7	760	−30.9	.....	33	−26.7	1,050	−31.7	.....	41	−24.2	1,210	−24.8
20 pounds	.....	21	−47.5	597	−45.7	.....	29	−35.5	930	−39.5	.....	35	−35.2	1,030	−36
Series E, July 15:															
None	.....	26	......	622	......	.....	28	......	823	......	.....	35	......	1,146	......
5 pounds	.....	26	0	680	+ 9	.....	24	−14.3	822	− .1	.....	36	− 2.9	1,137	− 0.8
10 pounds	.....	21	−19.2	585	− 6	.....	23	−18	718	−12.7	.....	33	− 5.8	1,005	−12.3
20 pounds	.....	21	−19.2	560	−10	.....	18	−36	434	−47.2	.....	30	−14.3	1,020	−11
Series F, August 5:															
None	.....	10	......	0	......	.....	13	......	0	......	.....	17	......	0	......
5 pounds	.....	10	0	0	......	.....	11	−15.4	0	......	.....	14	−17.6	0	......
10 pounds	.....	8	−20	0	......	.....	12	− 7.7	0	......	.....	14	−17.6	0	......
20 pounds	.....	9	−10	0	......	....	8	−38.4	0	......	.....	13	−23.5	0	......

An examination of the data given in Table 7 shows generally that the growth was checked and the fruiting decreased by the borax. A record of the height of the plants, made when the crop was young, shows that the growth was checked in the very beginning by the borax. The degree of injury, however, varies with the different plantings and with the different methods of applying the fertilizers. The germination was rather irregular where 20 pounds of borax were applied, and in spots the young cotton died. The use of 10 pounds of borax had a decided effect on the color of the foliage in each experiment, as the foliage was much lighter where the borax was applied. The 5-pound application of borax produced the least injury.

In section 3, where 5 pounds of borax per acre were applied, no injury was observed in series A, B, and C, and the reduction noted in the fruiting of the plants in series A and B was not serious. With 10 pounds of borax there was a further decrease in growth and, in general, in the number of bolls formed. Where 20 pounds of borax were used there was a decided harmful effect. In series C, D, E, and F there was a reduction in growth of 22, 35.2, 14.3, and 23.5 per cent respectively; and in series C, D, and E a reduction in boll formation of 10.2, 36, and 11 per cent, respectively.

In section 2, where the fertilizer was applied in the drill and the seed planted immediately, the harmfulness of borax with 10 and 20 pounds per acre was quite marked, especially in series D, E, and F, and the fruiting in series A was adversely affected. The growth was checked more in this section than where the fertilizer was sown broadcast. The use of 5 pounds per acre reduced growth to a much less extent than the 10 or 20 pound applications.

In section 1, where the planting was not made until after the fertilizer was applied, the harmfulness of the borax was on the whole less than in sections 2 and 3, except in series D and E, which is probably due to drier soil conditions.

In connection with the rainfall record, it was stated that the moisture condition of the soil was about optimum at the time and after the plantings were made in series A, B, and C. The rainfall was, however, very light during the weeks of July 4 and July 11 and was again light the weeks of July 25 and August 3. The effect of the borax in series D and E, which were planted in the period of dry weather, was more severe than in the experiments which were planted when the moisture was more nearly normal. For example, in section 1, 20 pounds of borax per acre reduced the growth 9.7 per cent in series C, 47.5 per cent in series D, and 19.2 per cent in series E. In section 2 the growth was reduced 29 per cent in series C, 35.5 per cent in series D, and 36 per cent in series E. In section 3 growth was reduced 22 per cent in series C, 35.2 per cent in series D, and 14.3 per cent in series E. The formation of bolls was also reduced more in series D and E than in C. A few days after the plantings were made in series D, E, and F, a light rain fell, which was followed by a dry period. While the plants were young in the earlier experiments there were occasional heavy rains, and at no time did the soil become very dry. It is not probable that a rainfall of 1 to 1.7 inches in one week distributed over a period of several days would wash very much borax out of reach of the roots of the cotton. However, it would result in the diffusion of the borax through the soil, and this diffusion might easily account for the lesser extent of injury in series A, B, and C. Under the rainfall conditions of series D and E the borax was concentrated in locations surrounding the roots of the young plants and would naturally cause a more severe injury and a greater retardation of growth.

The data in general show that the action of borax on cotton under the weather conditions prevailing at the time of this test was decidedly harmful when 20 pounds per acre were applied in the drill or sown broadcast. This quantity showed harmful effects whether the seed was planted immediately after the fertilizers were applied or whether they were planted after the intervening of a light rain. The use of 10 pounds per acre decidedly checked growth when applied in the drill, but was only slightly harmful when sown broadcast.

FIELD EXPERIMENTS USING FERTILIZERS WITH AND WITHOUT BORAX.

A COMPARISON OF TWO GRADES OF SEARLES LAKE POTASH IN THE FIELD.

In connection with certain studies in commercial fields to determine the comparative effectiveness of different potash carriers on the potato, a test of two grades of muriate of potash from Searles Lake was included. The two grades differed in that one, the so-called 1919 grade, contained 6.25 per cent of borax, while the other grade, designated 1920, contained practically none.

The tests were conducted cooperatively in Virginia, New Jersey, and Maine, as follows:

At Cape Charles, Va., in cooperation with the Virginia Truck Experiment Station; on Sassafras sandy loam; fertilizer application, 1,800 pounds per acre; average control, 7–8–0; variety grown, Irish Cobbler; yield, 161.7 bushels per acre.

At Norfolk, Va., in cooperation with the Virginia Truck Experiment Station; on Norfolk sandy loam; fertilizer application, 1,800 pounds per acre; average control, 7–7–0; variety grown, Irish Cobbler; yield, 221.3 bushels per acre.

At Holmdel, N. J., in cooperation with the New Jersey Agricultural Experiment Station; on Sassafras loam; fertilizer application, 1,500 pounds per acre; average control, 4–10–0; variety grown, American Giant; yield, 246 bushels per acre.

At Presque Isle, Me., in cooperation with the Maine Agricultural Experiment Station; on Caribou loam; fertilizer application, 1,800 pounds per acre; average control, 5–10–0; variety grown, Irish Cobbler; yield, 243.7 bushels per acre.

The detailed results are shown in Table 8.

The data in Table 8 disclose the fact that in most of the tests, especially as the quantity of borax was increased, the yields were reduced. At two of the stations the fertilizer mixtures containing the 1919 potash salt (6.25 per cent borax) were applied in two ways: (1) by means of the planter which applies the fertilizer in a furrow made by the planter plow and (2) by means of a fertilizer distributer which gives a somewhat greater spread to the application. It will be noted that the former method, which presumably afforded a greater concentration of the fertilizer-borax mixtures near the potato seed pieces, gave the poorer results. The fertilizer mixtures containing the so-called 1920 grade of potash salt (practically free from borax) gave excellent returns, comparing very favorably with other potash carriers.[4] In the experiment at Holmdel, N. J., it will be observed that the fertilizer-borax mixtures gave better results than the no-borax mixtures when applied with the distributer. The chief explanation for this lies perhaps in the heavy rainfall following planting which undoubtedly was sufficient to reduce the concentration of the borax to a point whereby stimulation, rather than injury, may have resulted to the extent of increasing the yields. When applied with the planter in the drill row, as is ordinarily done by the potato grower, the degree of injury was considerable, as is shown in the first figure column of Table 8. It is well to state in this connection that the results obtained during the same season at New Brunswick, N. J. (*2*), tend to support the foregoing explanation. At New Brunswick it was found that a fairly high concentration of borax was required to produce injury, and it is significant, moreover, that the rainfall there, which would be approximately the same as at Holmdel, was quite heavy.

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[4] A report on the effect of various potash salts upon crop yields on prominent soil types is in course of preparation.

TABLE 8.—*Total yields of potatoes grown on different types of soil treated with fertilizers of stated composition, applied at given rates per acre, and containing varying percentages of borax, tests of 1920.*

Items of comparison.	Application of muriate of potash.			Composition of fertilizer (per cent).		
	With planter in drill row, 1919 grade.	With distributer.				
		1919 grade.	1920 grade.	NH_3.	P_2O_5.	K_2O.
At Cape Charles, Va., on Sassafras sandy loam:						
Potash (K_2O) per acre..........pounds..	....	54	54	7	8	3
Borax ($Na_2B_4O_7$) per acre..........do....	....	8.85	....			
Yield per acre..........bushels..	....	178.1	203.6			
Potash (K_2O) per acre..........pounds..	....	90	90	7	8	5
Borax ($Na_2B_4O_7$) per acre..........do....	....	14.75	....			
Yield per acre..........bushels..	....	161.9	199.7			
Potash (K_2O) per acre..........pounds..	....	126	126	7	8	7
Borax ($Na_2B_4O_7$) per acre..........do....	....	20.65	....			
Yield per acre..........bushels..	....	127.4	228.9			
At Norfolk, Va., on Norfolk sandy loam:						
Potash (K_2O) per acre..........pounds..	....	54	54	7	7	3
Borax ($Na_2B_4O_7$) per acre..........do....	....	8.85	....			
Yield per acre..........bushels..	....	221.1	245.9			
Potash (K_2O) per acre..........pounds..	....	90	90	7	7	5
Borax ($Na_2B_4O_7$) per acre..........do....	....	14.75	....			
Yield per acre..........bushels..	....	231.8	232.5			
Potash (K_2O) per acre..........pounds..	....	126	126	7	7	7
Borax ($Na_2B_4O_7$) per acre..........do....	....	20.65	....			
Yield per acre..........bushels..	....	193.6	229.8			
At Holmdel, N. J., on Sassafras loam:						
Potash (K_2O) per acre..........pounds..	45	45	45	4	10	3
Borax ($Na_2B_4O_7$) per acre..........do....	7.5	7.5	....			
Yield per acre..........bushels..	262	284	278			
Potash (K_2O) per acre..........pounds..	75	75	75	4	10	5
Borax ($Na_2B_4O_7$) per acre..........do....	12.5	12.5	....			
Yield per acre..........bushels..	256.0	292.6	285.3			
Potash (K_2O) per acre..........pounds..	105	105	105	4	10	7
Borax ($Na_2B_4O_7$) per acre..........do....	17.5	17.5	....			
Yield per acre..........bushels..	226.0	293.3	276.0			
At Presque Isle, Me., on Caribou loam:						
Potash (K_2O) per acre..........pounds..	54	54	54	5	10	3
Borax ($Na_2B_4O_7$) per acre..........do....	8.85	8.85	....			
Yield per acre..........bushels..	331.4	355.5	340.2			
Potash (K_2O) per acre..........pounds..	90	90	90	5	10	5
Borax ($Na_2B_4O_7$) per acre..........do....	14.75	14.75	....			
Yield per acre..........bushels..	301.5	346.0	368.0			
Potash (K_2O) per acre..........pounds..	126	126	126	5	10	7
Borax ($Na_2B_4O_7$) per acre..........do....	20.65	20.65	....			
Yield per acre..........bushels..	232.1	311.7	405.9			

At the other stations the fertilizer-borax mixtures were injurious and when applied in the drill caused lower yields than when applied with a fertilizer distributer. The illustrations shown in Plate VII, Figures 1 and 2, and Plate VIII, Figures 1 and 2, will give some idea of the effect of borax in fertilizer upon the yield of potatoes on two soil types.

What is brought out here as well as in other parts of this bulletin is convincing proof that borax caused injury. Even were the rainfall heavy in one section, thereby mitigating the injury, it does not follow that the same weather conditions would prevail elsewhere or in another season, and since it has been definitely brought out herein that borax is quite apt to be harmful, it should be practically eliminated from fertilizer salts. Fortunately, this is already fully recognized. The fact is further brought out from the field tests on several soil types that practically borax-free potash salts give good results.

FURTHER RESULTS WITH POTATOES AND CORN.

Results obtained with potatoes and corn at New Brunswick, N. J. (*2*), and with potatoes at Presque Isle, Me.,[5] are again referred to here, with certain tabular presentations of yields and rainfall data, in order that the results may be assembled in their entirety, the details having been presented elsewhere.

The plan of the experiments in New Jersey and in Maine was similar to that at Arlington, Va., particularly as applies to the quantity of borax used. In New Jersey, fertilizer at the rate of 1,500 pounds per acre was applied to potatoes and at the rate of 400 pounds to corn; and in Maine, at the rate of 2,000 pounds to potatoes. The results are presented in Tables 9, 10, and 12.

TABLE 9.—*Effect of various quantities of borax on potatoes in plats on Sassafras loam at New Brunswick, N. J., in 1920.*

[Fertilizer application, 1,500 pounds per acre; variety grown, Irish Cobbler.]

Borax per acre.	Yield per plat (pounds).								
	Sec. 1.—Fertilizer applied in drill some time previous to planting.			Sec. 2.—Fertilizer applied in drill at time of planting.			Sec. 3.—Fertilizer applied broadcast at time of planting.		
	Primes.	Seconds.	Total.	Primes.	Seconds.	Total.	Primes.	Seconds.	Total.
None (check 1)	78.25	7.50	85.75	75.50	5.50	81.00	58.25	7.50	65.75
1 pound	64.20	5.75	69.95	56.30	6.85	63.15	41.40	5.00	46.40
2 pounds	75.55	4.65	80.20	72.50	9.00	81.50	58.05	5.80	63.85
3 pounds	75.65	6.65	82.30	65.60	9.10	74.70	60.15	5.75	65.90
None (check 2)	79.75	7.70	87.45	62.95	10.35	73.30	65.70	4.45	70.15
4 pounds	88.35	6.40	94.75	69.55	7.60	77.15	66.35	4.95	71.30
5 pounds	85.20	6.00	91.20	77.15	4.65	81.80	62.20	8.00	70.20
10 pounds	88.60	5.90	94.50	64.55	6.45	71.00	60.80	5.10	65.90
None (check 3)	86.90	5.75	92.65	67.75	8.60	76.35	65.80	4.10	69.90
20 pounds	85.70	3.75	89.45	68.75	6.90	75.65	79.00	3.00	82.00
30 pounds	76.95	3.00	79.95	55.00	3.85	58.85	74.00	3.55	77.55
50 pounds	67.95	3.55	71.50	25.35	1.40	26.75	45.70	2.00	47.70
None (check 4)	65.15	7.65	72.80	60.35	6.00	66.35	66.85	6.55	73.40
100 pounds	43.75	3.00	46.75	2.00	1.00	3.00	1.25	.50	1.75
200 pounds	22.50	1.25	23.75	None.	.125	.125	None.	None.	None.
400 pounds	4.00	.50	4.50	None.	None.	None.	None.	None.	None.

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[5] Brown B. E. Effect of borax in fertilizer on the growth and yield of potatoes. U. S. Dept. Agr. Bul. 998, 8 p., 1 fig., 4 pl. 1922.

In section 1 of Table 9 it is shown that the yields of potatoes were not greatly influenced by the borax until large quantities were applied. In this section the fertilizer-borax mixtures were applied some time before planting, and during this period the rainfall was at times quite heavy. In section 1 an application of 100 pounds was required before any marked depression in the yield took place.

In section 2, where the fertilizer-borax mixtures were applied and planting done immediately, the first obvious depression in yield took place with the 30-pound application of borax.

In section 3, where the fertilizer-borax mixtures were sown broadcast as much as practicable, no distinct depression in yield can be attributed to concentrations of borax under 50 pounds.

TABLE 10.—*Effect of various quantities of borax on corn in plats on Sassafras loam at New Brunswick, N. J., in 1920.*

[Yields stated in pounds, air-dry basis; fertilizer application, 400 pounds per acre.]

Borax per acre.	Grain.			Cobs.			Stalks.		
	Sec. 1.[a]	Sec. 2.[b]	Sec. 3.[c]	Sec. 1.[a]	Sec. 2.[b]	Sec. 3.[c]	Sec. 1.[a]	Sec. 2.[b]	Sec. 3.[c]
None (check 1)	11.30	19.88	19.59	2.43	4.32	4.33	24.25	22.00	21.40
1 pound	7.96	16.79	17.39	1.63	3.73	3.44	25.00	26.95	18.90
2 pounds	8.87	14.93	20.53	1.81	3.18	4.33	23.00	25.75	23.60
3 pounds	14.30	13.36	16.79	3.05	2.69	3.44	21.15	18.20	20.80
None (check 2)	13.47	13.00	13.91	2.81	2.35	2.82	19.30	18.55	20.20
4 pounds	9.82	12.00	11.97	2.07	2.50	2.36	14.60	17.50	17.05
5 pounds	8.79	8.60	9.97	2.00	1.65	2.04	14.20	12.55	13.80
10 pounds	10.85	9.47	11.73	2.30	1.97	2.61	14.85	15.90	16.70
None (check 3)	7.95	11.68	15.90	1.83	2.44	3.16	18.70	16.52	19.85
20 pounds	8.64	9.24	13.90	1.93	1.78	2.84	18.10	15.13	21.05
30 pounds	11.77	7.57	12.63	2.67	1.99	2.86	22.95	16.70	21.70
50 pounds	11.08	3.41	6.79	2.62	.92	1.66	18.75	7.30	15.65
None (check 4)	10.55	19.12	20.90	2.23	4.27	4.90	22.50	24.35	31.50
100 pounds	6.44	.62	2.82	1.76	.19	.86	20.90	1.70	9.40
200 pounds	1.23	0	0	.32	0	0	2.60	0	0
400 pounds	.40	0	0	.15	0	0	2.70	0	0

[a] Fertilizer applied in drill some time previous to planting.
[b] Fertilizer applied in drill at time of planting.
[c] Fertilizer applied broadcast at time of planting.

In the corn experiment (Table 10) the normal fertilizer and fertilizer-borax mixtures were applied at the rate of 400 pounds per acre; the quantity of borax, however, was the same as that applied to the potatoes.

In section 1 very little depression in yield, if any, occurred below the 50-pound application, but with quantities in excess of 50 pounds the injury was quite severe.

In section 2 the yields are somewhat confusing, but there was some indication that, beginning with the 5-pound application, some injury ensued, although it will be noted that with applications of 10 and 20 pounds per acre the yields were approximately the same as with the 5-pound application.

In section 3 some evidence is shown that, under the seasonal conditions prevailing, fairly high concentrations of borax were required to produce serious injury.

It will be noted (Table 11), as previously brought out, that the rainfall at New Brunswick during the growing season of 1920 was unusually heavy, which probably reduced the concentration of borax through solution and diffusion into the soil mass. At other stations

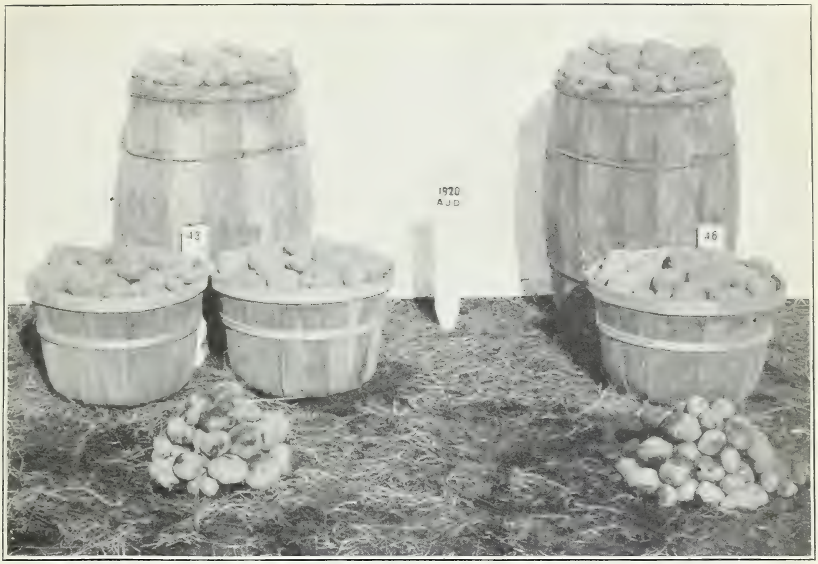


FIG. 1.—COMPARISON OF PLATS 43 AND 46.

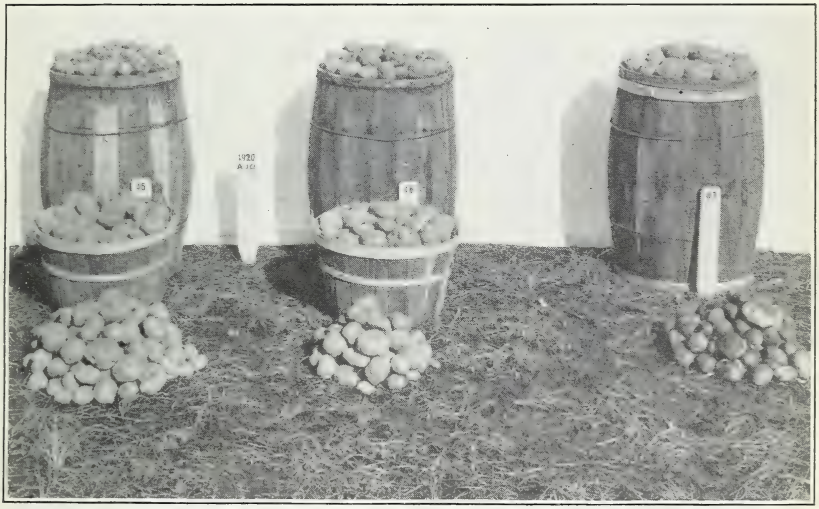


FIG. 2.—COMPARISON OF PLATS 45, 46, AND 47.

EFFECT OF BORAX ON POTATOES AT CAPE CHARLES, VA.

Quantities of borax applied per acre: Plat 43, none; plat 45, 8.85 pounds; plat 46, 14.75 pounds plat 47, 20.65 pounds. Soil, Sassafras sandy loam; area of each plat, one-fortieth acre.

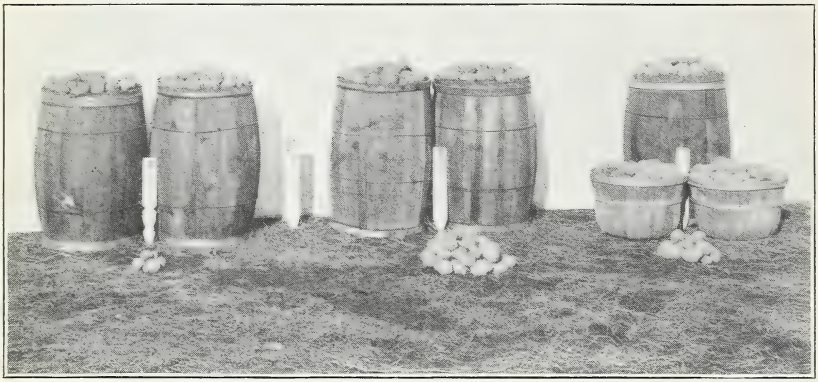


FIG. 1.—EFFECT OF BORAX ON POTATOES AT NORFOLK, VA.

Quantities of borax applied per acre: Plat 45 (at left), 8.85 pounds; plat 46 (in center), 14.75 pounds; plat 47 (at right), 20.65 pounds Soil, Norfolk sandy loam; area of each plat, one-fortieth acre.

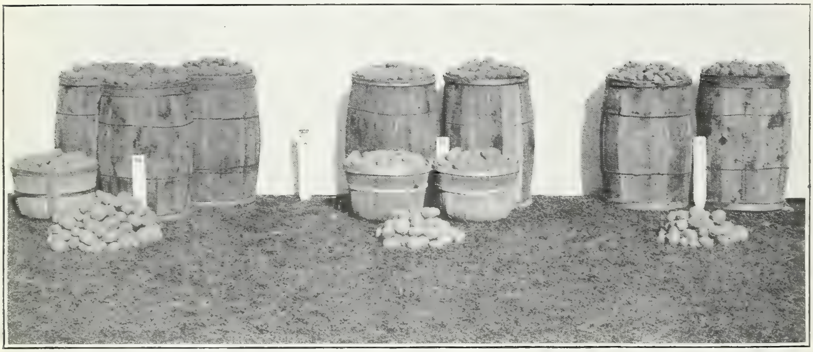
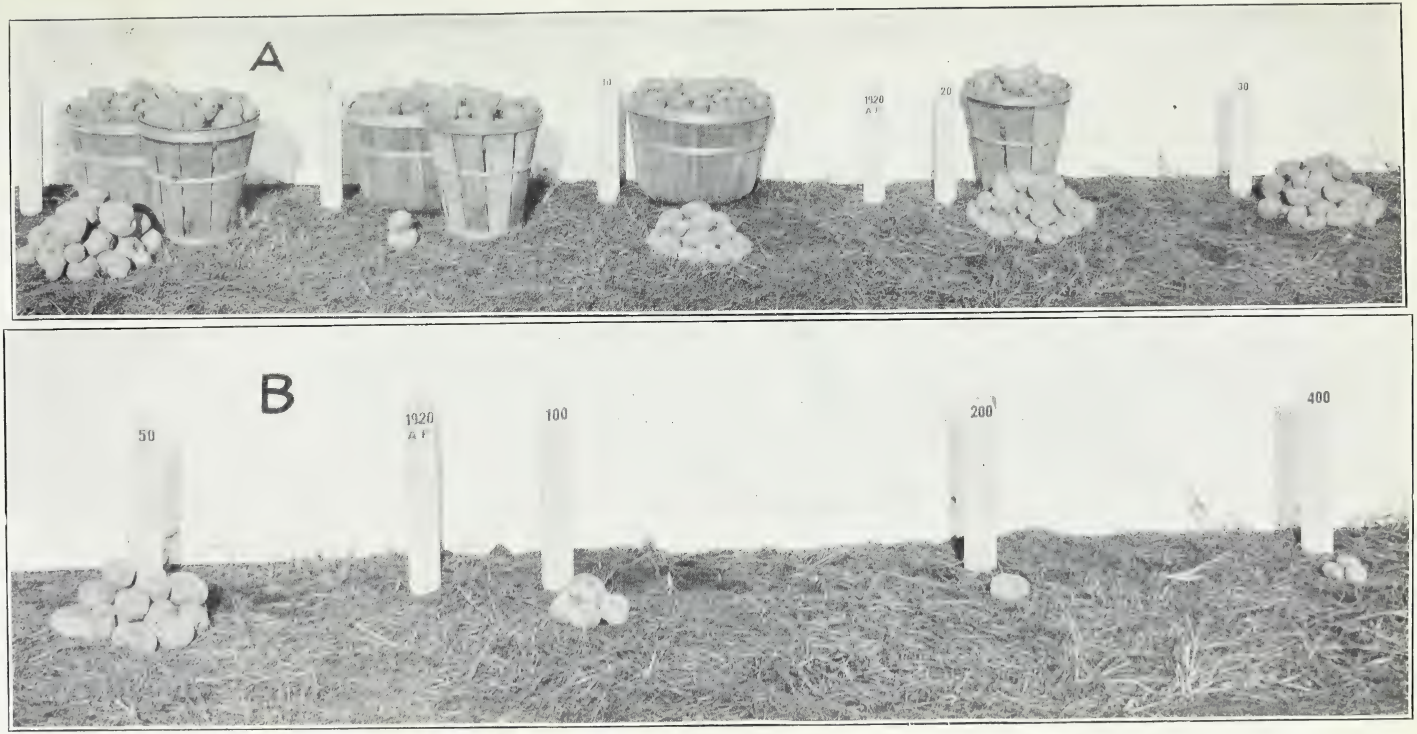


FIG. 2.—EFFECT OF BORAX ON POTATOES AT PRESQUE ISLE, ME.

Quantities of borax per acre applied with fertilizer: Plat 44 (at left), none; plat 47 (in center, applied with distributer), 20.65 pounds; plat 50 (at right, applied in the furrow with planter), 20.65 pounds. Soil, Caribou loam; area of each plat, one-fortieth acre.



YIELDS OF POTATOES FROM 1/200 ACRE WITH VARIOUS QUANTITIES OF BORAX IN FERTILIZERS.

On Caribou loam. Fertilizer applied at time of planting: *A*, No borax, 5, 10, 20, and 30 pounds of borax per acre, respectively; *B*, 50, 100, 200, and 400 pounds of borax per acre, respectively.

where the rainfall was not so heavy and was more uniformly distributed the injurious action of borax was much greater.

TABLE 11.—*Record of rainfall at New Brunswick, N. J., during the growing season, in 1920.*

[Data in inches.]

Items of comparison.	Apr.	May.	June.	July.	Aug.	Sept.
1920	4.28	3.56	9.64	6.00	8.21	2.23
10-year average, 1910 to 1919	3.66	3.85	3.52	4.67	5.07	2.95

Table 12 shows the results obtained with potatoes in Maine.

TABLE 12.—*Effect of various quantities of borax on potatoes in plats on Caribou loam, at Presque Isle, Me., in 1920.*

[Yields in bushels per acre; variety grown, Irish Cobbler; fertilizer application, 2,000 pounds per acre.]

Borax per acre.	Sec. 1.[a]	Sec. 2.[b]	Sec. 3.[c]	Borax per acre.	Sec. 1.[a]	Sec. 2.[b]	Sec. 3.[c]
None (check 1)	362.7	326.6	337.3	20 pounds	201.3	150.7	200.0
1 pound	370.0	349.3	318.7	30 pounds	118.7	52.0	81.3
2 pounds	381.3	362.7	324.0	50 pounds	88.0	26.7	56.7
3 pounds	390.7	305.3	304.0	None (check 4)	338.7	294.7	321.7
None (check 2)	342.7	376.0	317.3	100 pounds	9.3	5.3	10.7
4 pounds	341.3	330.3	328.0	200 pounds	4.0	1.3	2.7
5 pounds	328.7	302.7	329.3	400 pounds	1.3	.67	1.3
10 pounds	293.3	228.0	264.0	None (check 5)	309.3	316.0	237.3
None (check 3)	348.0	350.7	313.3				

[a] Fertilizer applied in drill some time previous to planting.
[b] Fertilizer applied in drill at time of planting.
[c] Fertilizer applied broadcast at time of planting.

In section 1, where borax was applied in the furrow, injury definitely occurred in the case of the 10-pound application of borax and became progressively worse. It will be noted, however, that the degree of injury was less than in section 2, where the borax was applied in the furrow and planting done immediately. The application of 1, 2, and 3 pounds of borax per acre apparently stimulated plant growth.

In section 2, the borax showed injury with the 5-pound application, and the injury with 10 pounds and larger quantities was great. The yields obtained from the plats receiving the large applications of borax, namely, 50, 100, 200, and 400 pounds per acre, are shown in Plate IX.

In section 3, the general trend of the results is fairly similar to that in sections 1 and 2, the first sign of injury occurring in the case of the 10-pound application of borax. In this section the method of applying the fertilizer-borax mixture in the case of the 400-pound application apparently depressed the yield of the last check.

The record for Presque Isle, Me. (Table 13), indicates that the rain which fell during June, subsequent to planting on June 5, was fairly well distributed. It would seem that there was hardly enough rainfall to cause the borax to be leached to any marked extent; in fact, only sufficient to keep the soil in good condition and the borax concentrated at the seed piece. The relation of the rainfall to the degree of injury sustained by the plants during the period is emphasized at this point, owing to the fact that the first three or four weeks after planting embraces germination and the early life of the plant.

TABLE 13.—*Record of rainfall at Presque Isle, Me., for June, July, and August, 1920.*

[Data in inches.]

Date.	June.	July.	Aug.	Date.	June.	July.	Aug.	Date.	June.	July.	Aug.
1		0.45	0.17	12			0.46	22	0.57		0.23
2	0.13			13		0.04		23	1.02	0.06	1.32
3	.50	.37	.63	14			.01	24	.10	.03	
4		.43		15			.01	25	.12	.02	
5		1.10		16	0.04	.09		26			.01
7	.73	.11		18		.03		27	.03		
8		1.00		19	.20	.42		29	1.09		
10			.43	20		.05		30	1.01	.08	.08
11	.49		.12	21	.06			31			.15

EFFECT OF BORAX ON COTTON AT MUSCLE SHOALS, ALA.[6]

PLANTINGS ON COLBERT SILT LOAM.

An experiment with cotton similar in plan to that at Arlington and at other locations with potatoes and corn was made on Colbert silt loam at Muscle Shoals, Ala. It included the application of fertilizer in the row as well as broadcast and also the immediate and delayed planting of seed after applying fertilizer. The quantity of borax used varied from 1 to 400 pounds per acre, and two rows each 70 feet long were used for each treatment. The fertilizers were applied on May 10. The rainfall for the month prior to starting the experiment and for a like period afterwards was exceedingly heavy. The soil became very compact from the excessive rains, and a very poor stand over the entire area was secured. The experiment was continued, however, in order to observe the effects of the borax, but a harvest was not made, as the broken stand appeared to make it useless.

TABLE 14.—*Effect of various quantities of borax on the growth of cotton on Colbert silt loam, at Muscle Shoals, Ala., in 1920.*

Borax per acre.	Fertilizer applied in the row.		Fertilizer applied broadcast at time of planting.
	At time of planting.	Planted 10 days later.	
None			
1 pound	Normal	Normal	Normal.
2 pounds	do	do	Do.
3 pounds	do	do	Do.
None			
4 pounds	do	do	Do.
5 pounds	Normal	Normal	Do.
10 pounds	do	do	Do.
None			
20 pounds	Slight injury	Slight retarding	Slight retarding.
30 pounds	Plants small; many dying	Somewhat stunted	Slightly retarded.
50 pounds	Germination low; plants dying.	Germination low; plants show yellowing.	Somewhat stunted.
None			
100 pounds	Only an occasional seed germinated; plants dying.	Germination about 50 per cent; plants dying.	Germination decreased and plants dying.
200 pounds	7 seeds germinated; plants about dead.	Only an occasional seed germinated; plants about dead.	Germination decreased about 70 per cent; most plants dead.
400 pounds	No germination	No germination	12 seeds germinated, and plants died.
None			

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[6] The immediate supervision of this experiment was under the direction of Dr. F. E. Allison, of the Fixed-Nitrogen Research Laboratory of the United States Department of Agriculture.

Borax caused the greatest injury to cotton in the early stages, either preventing germination or in lesser amounts merely retarding growth and preventing chlorophyll formation. A record of observations three weeks after planting is given in Table 14.

The quantity of borax required to produce a noticeable injury to cotton receiving fertilizer in the row was 20 pounds. Fifty pounds were necessary to appreciably lower germination and cause the death of any very large percentage of the plants. Where the fertilizer was used in the row and planting delayed for 10 days the injury seemed to be decreased about 50 to 75 per cent. Distributing the fertilizer broadcast decreased the injurious effects as much or possibly slightly more than delaying planting. It is shown that any method employed which decreased the concentration of the borax around the plant roots markedly decreased the injury.

During the 10 days preceding planting, May 1 to 10, 2.06 inches of rain fell, and for the 10-day period following planting 3.34 inches of rain fell. The second day after planting 1.6 inches precipitation occurred, which was followed by light showers for several days. The seventh day after planting there was a rainfall of 1.56 inches. The total rainfall for the month was 5.70 inches.

Even with this great depth of rainfall there was unquestionable injury from the borax with 30 pounds per acre. With 50 pounds per acre germination was low, and many of the plants died after germinating when the fertilizer was put in the drill and seed planted immediately. When the borax was sown broadcast the plants were stunted. With 100 pounds of borax per acre and over there was practically no germination.

PLANTINGS ON CLARKSVILLE SILT LOAM.

An experiment at Muscle Shoals, Ala., was also made on Clarksville silt loam located on a gentle slope and well drained. The soil is fairly retentive of moisture and does not become compact. The plan of the experiment differed somewhat from that at Arlington, Va., with cotton in that the fertilizer was applied only in the drill and the seed planted immediately, as in section 2 of the Arlington test (see Table 7). The 4–8–4 fertilizer was used at the same rate of application per acre, namely, 1,000 pounds, and borax applied at 5, 10, and 20 pounds per acre. The test was repeated six times; the first test was started on June 12, and the others followed at intervals of about one week. The separate plats are designated as series A, B, C, D, E, and F. The Cleveland Big-Boll variety was used.

Table 15 shows the results for this set of plats, including the height of the cotton plants at intervals during growth, the number of bolls which formed, and the green and dry weights of the plants, including the roots. Table 16 shows the weekly record of rainfall, so that the relation of the rainfall to the degree of harmfulness of borax in the different series can be compared. The effects of borax on germination, growth, and boll formation are noted. The cotton did not mature, so no yield records were obtained.

TABLE 15.—*Effect of various quantities of borax on the growth of cotton on Clarksville silt loam at Muscle Shoals, Ala., in 1920.*

Experiment, date started, and borax per acre.	Average height of plants (inches).			Bolls Oct. 26.	Green weight of plants.		Dry weight of plants (lbs.).
	July 28.	Aug. 20.	Oct. 16.		Pounds.	Increase or decrease (per cent).	
Series A, June 12:							
None	12.9	25.3	45.5	667	93.0	....	36.0
5 pounds	9.6	21.8	44.4	583	86.0	−7.5	33.5
10 pounds	7.1	17.3	42.1	456	85.0	−8.6	32.0
20 pounds	4.9	13.2	32.6	242	44.0	−52.7	15.0
Series B, June 19:							
None	12.0	28.6	50.0	716	104.0	....	40.0
5 pounds	10.5	25.7	43.3	563	84.0	−19.2	34.5
10 pounds	8.0	24.1	43.0	576	78.0	−25.	31.5
20 pounds	6.9	15.6	39.1	383	63.0	−39.4	25.0
Series C, June 26:							
None	9.4	18.1	45.2	337	86.0	....	34.0
5 pounds	6.3	15.1	40.5	220	78.0	− 9.3	28.5
10 pounds	6.9	12.9	39.9	224	75.0	−12.8	26.0
20 pounds	5.0	9.6	31.5	97	43.0	−50.	15.0
Series D, July 3:							
None	6.2	16.1	42.2	112	63.0	....	25.5
5 pounds	5.2	15.1	41.6	94	62.0	− 1.6	24.0
10 pounds	4.1	12.0	32.9	92	59.0	− 6.3	23.0
20 pounds	3.2	7.2	29.3	53	39.0	−38.1	13.0
Series E, July 11:							
None	....	12.3	36.8	45	55.0	....	17.5
5 pounds	....	11.5	33.7	48	56.5	+ 2.7	20.0
10 pounds	....	9.9	31.3	46	50.5	− 8.2	20.0
20 pounds	....	8.4	26.1	14	38.0	−30.9	11.0
Series F, July 20:							
None	....	10.0	28.2	5	46.5	....	15.0
5 pounds	....	8.9	29.1	7	47.0	+ 1.1	15.0
10 pounds	....	8.7	25.7	4	41.0	−11.8	11.0
20 pounds	....	7.6	22.4	1	35.0	−24.8	8.0

TABLE 16.—*Temperature and rainfall at Florence, Ala. (near Muscle Shoals), in June and July, 1920.*

Week of—	Rainfall (inches).	Temperature (°F.).		Week of—	Rainfall (inches).	Temperature (°F.).	
		Max.	Min.			Max.	Min.
June 6 to 12	0	97	53	Aug. 1 to 7	0	94	60
13 to 19	.52	98	63	8 to 14	5.10	90	66
20 to 26	.58	92	56	15 to 21	4.46	91	64
27 to July 3	.08	93	61	22 to 28	.59	91	56
July 4 to 10	.76	94	62	29 to Sept. 4	.42	96	61
11 to 17	.98	93	61	Sept. 5 to 11	2.17	93	55
18 to 24	1.50	98	63	12 to 18	.32	93	55
25 to 31	.06	95	57	19 to 25	.54	92	55
				26 to Oct. 2	0	92	37

The relation of rainfall to the degree of harmfulness of borax to cotton is apparent from a study of Tables 15 and 16, and this has been considered in detail in an earlier paper.[7] From the results of the experiment as a whole it will be observed that 5 pounds of borax per acre produced some injury to cotton when applied in the rows, and larger quantities showed even greater toxic effects. The results are in harmony with those obtained at Arlington, Va., showing that borax in small amounts is harmful to cotton and that its effect is influenced to a certain degree by weather conditions. Wherever light rains occurred soon after planting, followed by a dry spell, the effect was severest. If heavy rains followed periodically after planting the effect was less severe.

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[7] Skinner, J. J., and Allison, F. E. The influence of fertilizers containing borax on the growth and fruiting of cotton. Unpublished manuscript.

THE RESIDUAL EFFECT OF BORAX.

In order to determine whether there was any residual effect of borax on the succeeding crop, the field which was used for beans, potatoes, and corn in the experiments at Arlington, Va., was planted to wheat in October, 1920, following the harvesting of summer crops. The soil was disked and harrowed and the seed drilled over the entire field.

As the wheat pushed through the soil, the plants in the drill rows immediately over the area where the borax fertilizer had been applied in quantities of 50, 100, 200, and 400 pounds per acre showed a bleached appearance, and the stand on the 200 and 400 pound plats was poor. Plants taken from the fertilizer drill rows are shown in Plate X. These plants weakened as the winter came on, and by early spring the stand was not more than 25 per cent on the plats with the 200 and 400 pound applications. At harvest time in June, 1921, the single drill rows immediately over the original fertilizer-borax drill row were cut separately and the weight of straw and grain is given in Table 17.

TABLE 17.—*Effect of borax on wheat planted after potatoes and corn which had received fertilizer containing borax in various quantities, at Arlington, Va., in 1920.*

Borax per acre.	Yield of wheat per plat (pounds).				Borax per acre.	Yield of wheat per plat (pounds).			
	Potato section.		Corn section.			Potato section.		Corn section.	
	Straw.	Grain.	Straw.	Grain.		Straw.	Grain.	Straw.	Grain.
1 pound	21.0	1.75	21	3.0	20 pounds	21.0	1.5	18	1.75
2 pounds	14.5	2.0	21	2.25	30 pounds	20.0	1.5	19	2.0
3 pounds	12.0	1.5	19	3.2	50 pounds	18.0	1.0	17	1.6
None	21.0	1.75	20	2.5	None	23.0	2.25	21	3.0
4 pounds	16.5	1.5	19	2.7	100 pounds	10.0	1.0	19	1.25
5 pounds	14.5	1.2	18	2.6	200 pounds	8.0	.75	12	1.0
10 pounds	17.0	1.2	17	2.75	400 pounds	4.0	.6	6	.75
None	26.0	2.0	18	2.25	None	19.0	1.6	18	2.0

The yield of straw and grain from each drill row in the potato section varies considerably among the checks. While the growth was less in the rows where the smaller quantities of borax were used, it was as great as in the rows which had received 20 and 30 pound applications, so it would be presumed that these decreases may be due to causes other than borax. The yield from the 50-pound plat is slightly under the no-borax plat, and where larger quantities of borax were used the yield is cut more than 50 per cent. A somewhat similar effect is noted in the corn section. It is apparent that the borax, when used in the higher quantities, still remained of sufficient concentration in the soil to exert a harmful residual effect on the succeeding crop. It should be remembered, however, that the soil was disked and not plowed in the preparation for the wheat, so there was very little mixing of the soil. The only plants which were damaged were those in the seed drill row immediately over the old fertilizer-borax drill row.

An interesting case was encountered where cotton in a commercial field was damaged by Searles Lake potash in 1919. This field was again planted to cotton in 1921. The growing crops for both seasons on the same field are shown in Plate XI. In Figure 1 of Plate XI (photographed August 27) is shown the cotton in 1919 which had been fertilized with a mixture analyzing 3 per cent NH_3, 8 per cent P_2O_5, and 3 per cent K_2O at the rate of 800 pounds per acre and in addition had received 100 pounds of Searles Lake potash containing 12 per cent of borax. This is a 12-acre field and yielded that year between 3 and 4 bales of cotton. The soil is the Norfolk sandy loam and is well suited for cotton production. In Figure 2 of Plate XI (photographed August 22) the field of cotton is shown as it appeared in 1921 after being fertilized with a similar mixture containing no borax, and it was estimated that the 12 acres would yield about 12 bales of cotton. From this it is apparent that all effects of the borax applied in 1919 had disappeared.

SYMPTOMS OF BORAX-AFFECTED PLANTS.

The descriptions of borax-affected plants as observed by the various investigators are here given in order that the reader may recognize the abnormal characteristics produced by this chemical, especially if compared with the photographs shown in this and the other papers cited. These characteristics are as follows:

Potatoes.—Potato plants affected by borax present rather striking characteristics, as noted in the field experiments reported. The seed piece often fails entirely to ence germinate, or it may be delayed in germination. When germination has failed, there was an ~~abundance~~ of decay in the seed piece even after the lapse of considerable time. In cases where germination is not seriously affected, the young sprouts are often killed. There is an absence of roots at the seed piece, but root development often occurs above the seed piece in the upper layers of soil. The small plants always have a poor root development. The stalks of affected plants are not as thick as those of normal plants and are very spindling, the leaves are small and narrowed, light in color, and bleached, or at least there is a marginal yellowing of the leaflet. This is prominent on the more severely injured and dwarfed plants. The yellowing is of a bright golden color and not the pale yellowing usually present in plants that are normally or prematurely ripening. In milder cases the abnormal color is restricted to the extreme edges of the leaves, particularly the lower ones. While the lower leaf was badly affected, young shoots formed on its axis would appear entirely healthy only to suffer the same difficulty in their later development. The dead tissues suggest more of an olive color than a green and resemble most closely a potato leaf which had been rapidly killed and quickly dried with little yellowing. The marginal injury appeared to be caused by an accumulation of borax. In severe cases the leaves at the top of the plant are noted as folded upward on the midrib. Commercial fields where borax caused injury presented a broken appearance in stand, with plants of irregular size, often very weak and spindling.

Corn.—The toxic action of borax on corn may result in the prevention or delay of germination and in distorted and bleached plants. In severe cases following germination the seedling has not sufficient vitality to push through the soil, and in such cases it withers and dies. The stalk frequently fails to develop its leaves after having pushed through the soil. With as small a quantity as 5 pounds per acre, borax was observed to produce a slight bleaching when the plant was 2 to 3 weeks old. Badly bleached and distorted plants resulted where larger quantities were present. The injury by borax is always at germination and during early growth, for if the stalks were not killed they finally produced good ears of corn. Young plants injured by borax tend to be lighter in color and in some cases are bleached entirely white. This prevention of chlorophyll formation may be due to an interference with the

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United States Department of Agriculture, Department Bulletin No. 1126, "The Effect of Borax on the Growth and Yield of Crops."

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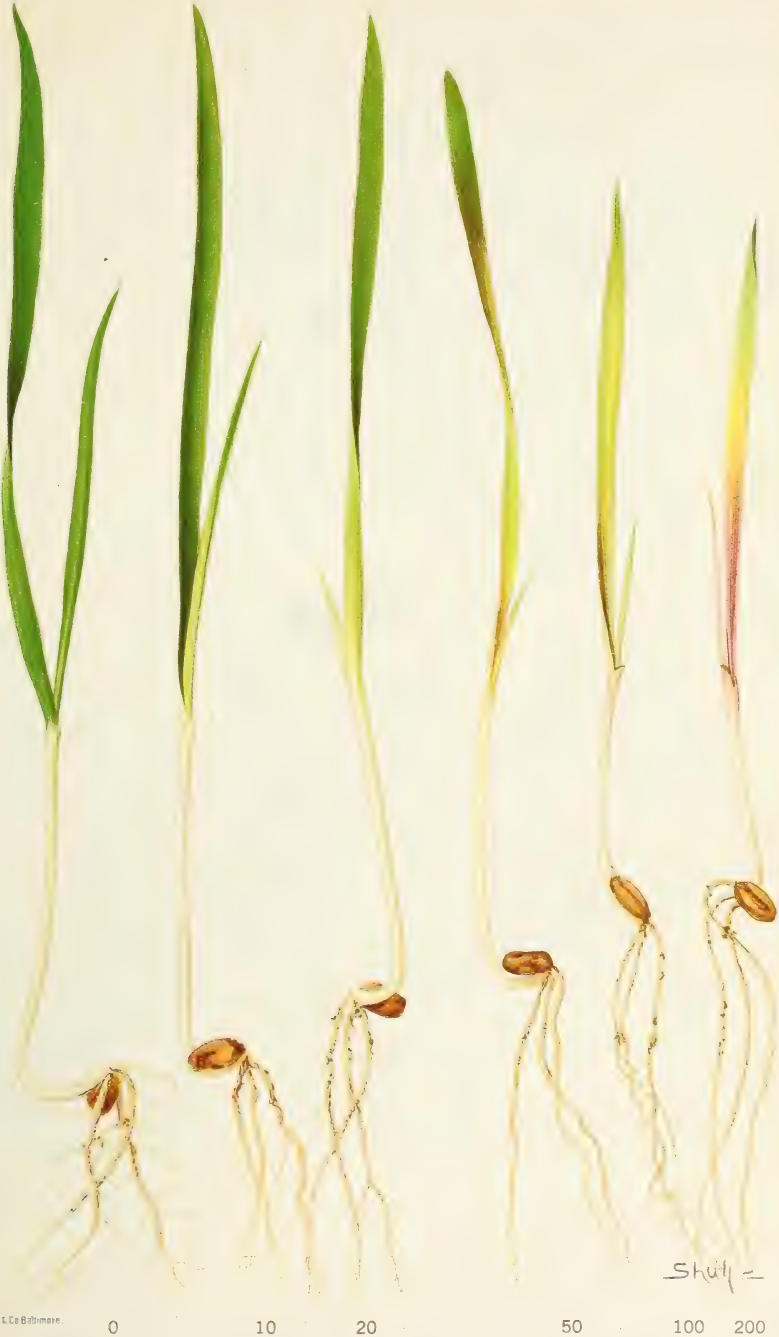

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EFFECT OF BORAX ON WHEAT PLANTED IN THE FALL FOLLOWING THE APPLICATION OF BORAX TO CROPS IN THE SPRING.

Injury to the wheat was shown only in the drill rows. The plants shown were taken from the fertilized drill rows of the previous crop: No borax, 10, 20, 50, 100, and 200 pounds of borax per acre, respectively.

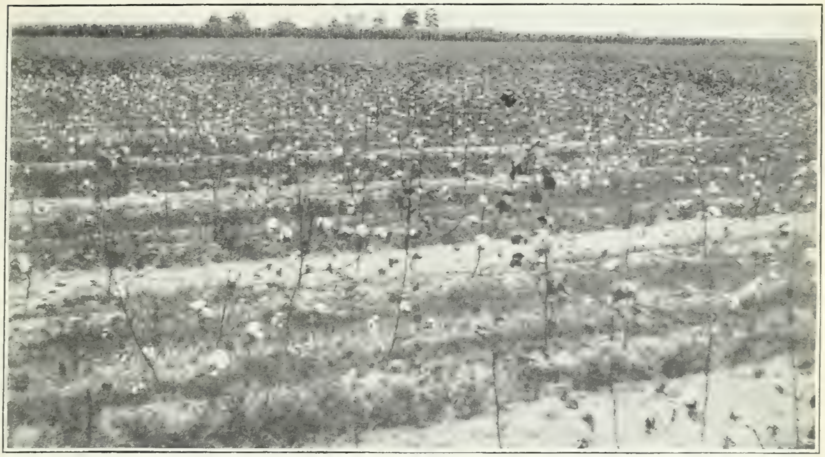

FIG. 1.—FIELD OF COTTON IN 1919.

Fertilized with 800 pounds of a 3-8-3 mixture plus 100 pounds of potash containing 12 per cent borax.

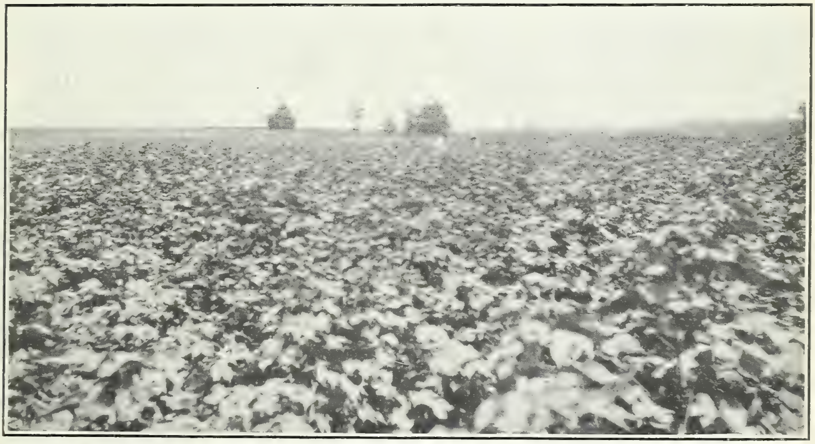

FIG. 2.—COTTON ON THE SAME FIELD IN 1921.

Fertilized with a similar mixture containing no borax. It is apparent that all effects of the borax applied in 1919 had disappeared.

EFFECT OF BORAX ON COTTON GROWN ON NORFOLK SANDY LOAM.

assimilation of iron, similar to the action of an excess of calcium, or, as observed, with an excess of manganese compounds. Injurious quantities of borax cause tipburn; in still stronger concentrations wilting ensues, first of the older leaves and then of the entire plant. Borax toxicity is also evidenced in the foliage by a banded bleaching of the chlorophyll of the leaves especially marked at the margins. The extreme tips are often killed, but not the margins. When the injury is less severe the leaves are at first streaked with pale green and may later regain their normal color.

Beans.—Borax is especially injurious to beans and is harmful at germination and retards development in the early stages of growth. The injury first appears on the margins of the first leaves which unfold, especially the tips. Where injury is severe, the entire leaf soon turns yellow, then white, which is followed by a killing of the tissues, working from the margin inward. It has been observed that the taproot of the bean plant was the most injured portion in the poisoned seedling. The root nodules were markedly reduced in size and number. In all cases of borax injury to beans, a dwarfed plant resulted with a final reduction of both vines and fruit.

Cotton.—Cotton plants affected by borax both in pots and under field conditions are weak, slender, and frequently die after having made a growth of an inch or two. At the time when the first pair of true leaves should appear, the seedlings show no apparent growth for several weeks, dead sections appearing along the margins of the seed leaves which eventually become dry, and the plant dies. Where injury is less, the plant shows a stunted growth and early maturity. The foliage shows a yellowed effect, and the leaves become dish shaped. The resultant effect is a broken stand, and plants in the field of the same age vary greatly in size. The yield is greatly reduced.

Tobacco.—Plummer and Wolf (*11*) describe the effects of borax on tobacco as follows: The roots of borax-affected plants are severely stunted, tend to be densely clustered near the end of the main root, and are all short and fibrous. The lower leaves are pale green, thicker, and less broad. The tissues most distant from the principal veins are palest and may become dead and dry. The leaf margins and tips are rolled downward and become rimbound. The root development of plants which made considerable growth is near the surface of the soil and near the tip of the main root, with few or no roots between these two groups. The stand in borax-treated fields is broken, and the plants lack uniformity in size.

It would appear from the symptoms described for the various crops that the main characteristics of borax-affected plants are (1) retarded germination; (2) general dwarfing of the plant including both roots and tops; (3) absence of normal color, which may be characterized by bleached and yellowed foliage, especially leaf tips and margins; and (4) reduced growth and yield.

SUMMARY.

The results presented herein show that borax proved to be harmful to plant growth. The experimental work was designed in order to preclude any other possible harmful factors. For one thing, practically pure borax was employed to mix with the fertilizers. The fertilizer itself was made from practically borax-free nitrogen, phosphoric acid, and potash salts. Varying quantities of borax, ranging from 1 to 400 pounds per acre were mixed with fertilizer and applied to the soil in three different ways. In order to properly compare the effect of the borax, one application of borax-free fertilizer was made in the same way and applied in the same quantity. Finally it was decided essential to carry on the experimental work on a number of soil types and with different crop plants as indicators of borax injury.

The results show that the potato can tolerate a greater quantity of borax than plants like corn or beans, which were injured by comparatively small quantities of borax. The degree of injury, however, was modified considerably according to the rainfall. Apparently the depth and distribution of rainfall is the most prominent factor concerned. Heavy rainfall in one section caused the borax to leach or diffuse into the soil mass, thereby enabling plants to withstand greater applications of it than in other sections where less rainfall had occurred and where only light applications were necessary to produce injury.

The way in which the fertilizer was applied exerted considerable influence, and in practically every case the fertilizer-borax mixtures drilled in the furrow, followed by immediate planting, produced much worse injury and with lower concentrations than by applying the fertilizer-borax mixtures some time before planting or by broadcasting and planting immediately.

The effect of borax on the germination and yield of Lima beans at Arlington, Va., was most noticed where the fertilizer-borax mixtures were applied in the furrow and planting done at once. Less than 50 per cent germinated with an application of 10 pounds of borax per acre, and with even less quantities the effect was marked. The 10-pound application of borax caused marked depression in the final yield of both vines and beans. In the section where the mixtures were sown broadcast, it required 20 pounds to produce injury, while in the section where the fertilizer-borax mixtures were applied in the drill some time before planting, 20 pounds also were required to produce injury.

The effect of borax on snap beans at Arlington, Va., was quite marked, injury being noticeable with small quantities of borax, and the yield was curtailed with an application of 5 pounds of borax per acre, and with quantities below 5 pounds the vines showed a color lighter than the no-borax plats.

The effect of borax on potatoes at Arlington, Va., when used in quantities less than 5 pounds per acre was one of stimulation. Where the borax application immediately preceded planting, 20 pounds of borax produced injury and a depression in yield. With the other methods of applying the borax mixtures the potato withstood greater concentration of borax.

Corn displayed a marked reaction to borax. In the case of immediate planting, where the fertilizer was drilled in the furrow, only 2 or 3 pounds of borax were required to produce lighter colored plants, and with 5 pounds marked discoloration ensued. When the fertilizer was sown broadcast no discoloration took place until 10 pounds or more of borax per acre had been applied.

Four pounds of borax in the drill depressed the yield of both stover and corn. When sown broadcast, 20 pounds were required to depress the yield. Practically no plant growth took place where the application exceeded 50 pounds of borax per acre.

The effect of borax on cotton in experiments conducted at Arlington, Va., and Muscle Shoals, Ala., was to severely injure the plants with 20 pounds of borax per acre and to slightly injure the plants with 10 pounds per acre. With high rainfall the degree of injury was slight, and with low rainfall the injury was more severe.

In experimental work in Virginia, New Jersey, and Maine the effect of borax was more marked on sandy soils than on the heavier soil types, and the effect of the borax was modified by rainfall.

Experimental work conducted at New Brunswick, N. J., with corn and potatoes on Sassafras loam showed strikingly the influence of rainfall, for it required comparatively high initial applications of borax to produce the degree of injury noted elsewhere.

The experiments on Caribou loam in Maine showed that 5 pounds of borax applied in the drill at the time of planting produced definite injury, but the methods of applying the fertilizer-borax mixtures, such as early application before planting and broadcasting, tended to reduce the degree of injury at the lower concentrations.

While there was evidence of borax remaining in the soil for a period of some months even with considerable rainfall, the injury was practically confined to the drill rows with high initial application of borax. In a commercial field under observation no injury could be observed the second year after the failure of the cotton crop caused by borax in the fertilizer used.

In all of the work where comparisons were made, it was shown that the potash salt from Searles Lake, Calif., when practically free from borax, gave satisfactory results as measured by actual yields.

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